REPORT

PFAS Detailed Site Investigation

Bandiana Military Area

Submitted to:

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Director Investigations East
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Submitted by:

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Key Messages

These key messages are the outcomes of a Detailed Site Investigation (DSI) of Per- and Polyfluoroalkyl Substances (PFAS) on and near the Defence Bandiana Military Area (BMA) in Wodonga, Victoria.

What was done?

The investigation involved multiple components of assessment and review to identify the extent of PFAS on and near the BMA.

PFAS are a class of manufactured chemicals that resist heat, stains, grease and water and therefore, have been used widely in many industrial applications. PFAS were used in aqueous film forming foams (AFFF), which are fire-fighting foams that have been used extensively worldwide, and within Australia, from about the 1970s by both civilian and military authorities. In May 2018, the Australian Department of Health Expert Health Panel for Per- and Poly-Fluoroalkyl Substances (PFAS) released their report to the Minister\(^1\). The panel’s key finding as highlighted in their summary report was as follows:

“Importantly, there is no current evidence that supports a large impact on a person’s health as a result of high levels of PFAS exposure. However, the Panel noted that even though the evidence for PFAS exposure and links to health effects is very weak and inconsistent, important health effects for individuals exposed to PFAS cannot be ruled out based on the current evidence.”

Given, however, that PFAS continue to persist in humans and the environment, the Panel noted that exposure to them should be minimised.

As part of a national program proactively initiated by Defence, an assessment was conducted to understand areas within the BMA where AFFF that contained PFAS was used or disposed of and to understand the potential contamination risks on both Defence’s property and within surrounding areas.

A sampling programme both within the BMA and the surrounding area was completed over a five month period from October 2017 to February 2018. The programme involved drilling bore holes to sample the groundwater, the collection of soil samples, and the collection of water and sediment samples from creeks, rivers, ponds, lakes and dams.

Prior to commencing the sampling program, a water use survey (WUS) was distributed to 2161 properties around the BMA to understand how people use water. This sampling programme collected and analysed the following:

- soil samples from 126 locations;
- sediment and / or surface water samples from 144 locations; and
- groundwater samples from 81 locations.

In addition, 27 samples were taken at locations where residents nearby the BMA use water sourced from surface water bodies or groundwater bores, or at points of possible exposure.

Samples were analysed by an independent laboratory (accredited by the National Association of Testing Authorities- NATA) for the presence and concentrations of PFAS.

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What was found?

The investigation provided an understanding of how PFAS may have moved and migrated, both on- and off-base, and how people, plants and animals may be connected or exposed to it. Understanding of the PFAS source areas, where AFFF containing PFAS was used on the BMA was also established.

Fifteen (15) potential source areas within the BMA were initially identified as locations where AFFF had either been used or disposed of. The sampling undertaken confirmed detectable PFAS levels in twelve (12) of these source areas.

PFAS was found in surface water, groundwater and soil samples collected within and around the BMA.

Results from the sampling programme suggests the main way that PFAS have moved off-base from South and North Bandiana is via surface water flow – via several drains, and unnamed creeks. PFAS have migrated in the surface water down Jack in the Box Creek towards Wodonga Creek, and via an unnamed creek towards the Kiewa River. PFAS migrating from the East Bandiana portion of the BMA, have moved both by surface water and groundwater. Both surface water and groundwater in this area flows towards the Kiewa River.

What are the key outcomes?

Within Australia, a tiered approach is used for the assessment of contaminated sites. The initial stage (Tier 1 Screening Risk Assessment) involves comparing the concentration of a contaminant against a guidance value. For PFAS, the current guidance values are presented by the Heads of EPA Australia and New Zealand (HEPA) within the PFAS National Environmental Management Plan (January 2018).

Concentrations below the guidance values are not considered to present a risk. If a concentration is above a guidance value, then Human Health and Ecological Risk Assessment and/or Risk Mitigation Measures may be required. A Human Health and Ecological Risk Assessment is used to confirm if an unacceptable risk exists, and if so, how significant that risk may be. Once the risks are further understood and technically evaluated, plans will be put in place to mitigate risks that are considered unacceptable.

Potential Human Health Risks – On-base:

Based on the sampling results within both the source areas and their surrounds on the BMA, and based on the way the land is used, the concentrations of PFAS in the soil are not considered to present a risk.

Surface water across the BMA was identified as having PFAS concentrations above the guidance values. However, as people do not swim in or routinely interact with the surface water, exposure is limited and the water is unlikely to present a risk. However, it is important to ensure appropriate health and safety precautions are implemented when people on the base are involved in either maintenance activities, or involved in training activities which use and/or involve surface water.

Within localised areas across North and South Bandiana the groundwater was identified as having PFAS concentrations above the guidance values. However, as the water table is generally deep, and groundwater is not extracted, these impacts are not considered to present a risk. However, within an area localised around the Petroleum, Oils and Lubricants facility (Source Area 9) on South Bandiana and beneath East Bandiana, the groundwater is not as deep. Therefore, it is important to ensure appropriate health and safety precautions are implemented for construction and maintenance activities which may encounter groundwater in these areas.

Due to the tendency for PFAS to accumulate within plants and animals, further investigation is required to assess if the PFAS identified on the base are accumulating in the sheep grazing on the base. The level of risk associated with this potentially complete pathway will be the subject of a Human Health Risk Assessment.
**Potential Human Health Risks – Off-base:**

Water extracted from Wodonga Creek - including that by North East Water for the municipal town supply – is below drinking water guidance values. As such, it is safe to continue to drink the municipal water supply.

Based on outcomes of other studies conducted in Australia, concentrations of PFAS in water equivalent to the drinking water guidance values were considered safe to use for garden, poultry and stock watering. The Human Health Risk Assessment will provide the mechanism of validating these findings considering the site specific data collected.

The soil, sediment and surface water PFAS concentrations along the majority of the Jack in the Box Creek (including along Arthur Dunstan Park), within Wodonga Creek, and within the main flowing channel of the Kiewa (where swimming and boating occur), were below the guidance values. Based on these current results collected in high flow conditions, it is safe to continue to swim in these areas.

However, PFAS in surface water sampled in two specific locations within Jack in the Box Creek immediately downstream of the base, and in surface water and sediment in the oxbow lakes to the east of East Bandiana, were higher than the guidance values. The level of risk in these areas will be the subject of a Human Health Risk Assessment.

Due to the tendency for PFAS to accumulate within plants and animals, further investigation is required to assess if the PFAS identified within the Jack in the Box Creek, Wodonga Creek and Kiewa River are accumulating in the food people are either growing or catching. The level of risk in these areas will be the subject of a Human Health Risk Assessment.

**Potential Ecological Risks:**

The concentrations of PFAS in soil, sediment and surface water, both on-base and off-base, were higher than the ecological screening values. It is worth noting that, due to the tendency for PFAS to accumulate in animals and magnify within ecological food chains, the ecological screening guidance values are very low. The level of risk to ecological receptors, such as fish and birds, will be the subject of an Ecological Risk Assessment.

**What are the next steps?**

The investigation findings have established a greater understanding of PFAS on and around the BMA, and identified that many of the potential PFAS exposure pathways do not present a risk to people both on and off the base. There is however, in specific areas as described above, the need to undertake further investigation to confirm if an unacceptable human health or ecological risks are present and what management / remedial measures need to be implemented.

To investigate these risks, the next step that will be undertaken is a Human Health and Ecological Risk Assessment (HHERA) and the development of the PFAS Management Area Plan (PMAP). This process will commence in the second quarter of 2018. The HHERA will involve collecting samples of water, fish and other aquatic biota that people and animals may eat.
Executive Summary

ES 1.0 Introduction

Golder Associates Pty Ltd (Golder) has been engaged by the Department of Defence (Defence) to undertake a detailed site investigation (DSI) of the nature and extent of Per- and Poly-Fluoroalkyl Substances (PFAS) within and surrounding the Defence Bandiana Military Area (BMA), Victoria (Plate i). This DSI presents the results of the initial PFAS source identification stages, where an understanding of the location and intensity of historical AFFF usage was developed, and the results of the sampling works completed between October 2017 and February 2018.

PFAS are a class of manufactured chemicals that have been used since the 1950s, and due to their unique attributes being resistant to heat, stains, grease and water, they have been used widely. PFAS were used in aqueous film forming foams (AFFF), which are fire-fighting foams that have been used extensively worldwide, and within Australia, from about the 1970s by both civilian and military authorities. AFFFs were used extensively due to their effectiveness in extinguishing liquid fuel fires. Older formulations of AFFF contained a number of PFAS that are now known to be persistent in humans and the environment. Historical activities at the BMA have involved the use of PFAS containing AFFF.

In May 2018, the Australian Department of Health Expert Health Panel for Per- and Poly-Fluoroalkyl Substances (PFAS) released their report to the Minister\(^2\). The panel’s key finding as highlighted in their summary report was as follows:

“Importantly, there is no current evidence that supports a large impact on a person’s health as a result of high levels of PFAS exposure. However, the Panel noted that even though the evidence for PFAS exposure and links to health effects is very weak and inconsistent, important health effects for individuals exposed to PFAS cannot be ruled out based on the current evidence.”

Given, however, that PFAS continue to persist in humans and the environment, the Panel noted that exposure to them should be minimised.

Defence has proactively initiated an investigation to identify the nature and extent of PFAS on and in the vicinity of the BMA where AFFF was historically used. Defence’s primary objective for the investigation at the BMA is to understand potential contamination risks on both Defence property and surrounding areas. The work is being done in consultation and communication with Federal and State government agencies as well as community residents and stakeholders.

ES 2.0 Site Setting

The BMA is located adjacent to the New South Wales (NSW)-Victorian border town of Wodonga, Victoria on approximately 650 hectares (ha) of land. The BMA is located approximately 3 kilometres from Wodonga town centre and 250 kilometres north-east of Melbourne. The BMA and surrounding land defined as the investigation area is presented below (Plate i).

The BMA comprises the following bases:

- Gaza Ridge Barracks (comprising and referred in this report as North Bandiana and South Bandiana).
- Wadsworth Barracks (comprising and referred in this report as East Bandiana).

There is a topographic divide that runs across the BMA in a general north - south direction. This divide separates the BMA into two catchments. West of the divide, the surface water and groundwater travels in a north-westerly direction, towards Wodonga Creek via Jack in the Box Creek. Wodonga Creek receives water from both Jack in the Box Creek and the Murray / Kiewa River. Wodonga Creek is the sole source of water for Wodonga and surrounding townships (extracted by North East Water). East of the divide, the surface water and groundwater travels in an easterly and north-easterly direction, towards the Kiewa River. The nature of the geology across the investigation area is complex and this likely impacts how water flows either above ground (as surface water) or as groundwater.

Based on the site setting, there is potential for PFAS contamination to be transported off-base via either soil / sediment, surface water, groundwater or biota (e.g. fish) in either the Jack in the Box Creek catchment (i.e. areas west and north-west of the site), or the Kiewa River catchment (i.e. areas east of the site).
ES 3.0 Scope of Works

The investigation was focused on the development of a robust Conceptual Site Model (CSM). The CSM describes the potential linkages between Sources, Pathways and Receptors (SPR) of PFAS contamination. The SPR linkages communicate the possible scenarios where receptors (i.e. humans or ecosystems) are potentially exposed to PFAS that have migrated via pathways from source areas on the BMA.

The investigations included the following scope of works:

- **Water Use Survey (WUS)** - a WUS was distributed via the post to 2161 properties to collect information about water supply and water use on the properties surrounding the BMA. Specific properties, such as those adjacent to the BMA or with licenced extraction bores were also approached via door knocking and / or direct mail (letter box drops). A total of 212 responses were received.

- **Source Area Assessment** - areas where AFFF containing PFAS was used (or disposed) were identified on the BMA, through a review of available site records and by interviewing both current and retired site personnel. Fifteen potential source areas were identified on the BMA.

- **Environmental Sampling** - the environmental sampling program was completed in accordance with an approved Sampling Analysis and Quality Plan (SAQP). An overview of the sampling locations are presented below (Plate ii) and included:
  - **Soil** sampling from a total of 126 locations both across the BMA and within surrounding areas.
  - **Sediment and surface water** sampling from 144 locations in drainage lines, creeks, rivers, ponds and lakes both within the BMA and within surrounding areas including the Kiewa River, Jack in Box Creek, Wodonga Creek and the Murray River.
  - **Groundwater** sampling from 81 groundwater monitoring wells.
  - **Point of Use** sampling at 27 specific points of water use or potential exposure.

- **Laboratory Analysis** - All environmental soil samples were analysed by independent laboratories (Australian Laboratory Services (ALS) and Eurofins), accredited by the National Association of Testing Laboratories (NATA) for the analysis of 28 individual PFAS chemicals.

- **Interpretation and Reporting** - the soil, sediment, surface water and groundwater field and analytical results were compared against applicable human health and ecological guidance values. These values are published by Australian government agencies including the Environment Protection Authority Victoria and provide concentrations of some PFAS chemicals above which there is the potential for there to be a higher risk to human or ecological health. Screening or comparing data against these values is called a Tier I assessment. Following these works, a CSM was then developed to understand the potential for human and ecological receptors to be exposed to unacceptable levels of PFAS sourced from the BMA. Based on this DSI, a Human Health and Ecological Risk Assessment is then used to confirm if an unacceptable risk exists, and if so, how significant that risk may be. Once the risks are further understood and technically evaluated, plans will be put in place to mitigate risks that are considered unacceptable. The results of the investigations and CSM are presented within this DSI Report.

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3 Due to confidentiality agreements, not all sampling locations are displayed
ES 4.0 Investigation Results

ES 4.1 Source Areas

The PFAS source assessment identified a total of 15 potential PFAS source areas across the BMA. These were areas of the site typically used for fire training activities, with selected areas also used for the waste disposal of AFFF products. The following areas were identified, and Plate vi provides an overview of their locations:

- **South Bandiana**
  - Source Area 1 (SA1) – Petroleum Platoon – Former Fire Training Ground.
  - Source Area 2 (SA 2) – Base Fire Services (BFS) – Former Fire Training Ground.
  - Source Area 4 (SA 4) – Former 25 m Firing Range.
  - Source Area 6 (SA 6) – Current Fire Training Area, Building 600.
  - Source Area 7 (SA 7) – Old Fire Station, Building 421.
  - Source Area 8 (SA 8) – Original Fire Station – Corner of Anderson Road and Donegon Road.
  - Source Area 9 (SA 9) – Petroleum, Oils and Lubricants (POL), Building 490.

- **North Bandiana**
  - Source Area 10 (SA 10) – Former Unit Training Area, between Warehouse 1 and 2.

Source Area 12 (SA 12) – Armoured Vehicle Maintenance Training, Building 100.

East Bandiana

Source Area 13 (SA 13) – Fire Station – Current.

Source Area 14 (SA 14) – Former Unit Training, Building 592.

Source Area 15 (SA 15) – Former Unit Training, Football Field.

In addition to the on-base potential source areas, the following were observed as notable potential off-base PFAS sources:

- Albury Airport located approximately 8.3 km north of North Bandiana (on the northern bank of the Murray River).
- The Wodonga Fire Station and the Country Fire Authority facility located approximately 2.7 km north-west of South Bandiana.
- The Wodonga West Fire Station located approximately 5.5 km north-west of South Bandiana.
- The Wodonga Waste Water Treatment Facilities operated by North East Water, including the Baranduda Waste Water Treatment Plant (WWTP) located in close proximity to (and south of) East Bandiana. It is noted that North East Water has indicated that the Baranduda WWTP is a pre-treatment facility receiving waste sewage from the BMA before subsequent transfer to the West Wodonga treatment plant.

Since approximately the 1990s, Defence has divested several portions of the previous BMA property, including parcels of land to the west of South Bandiana and east of North Bandiana. The divested land to the west, included an area identified in previous investigations as being a former landfill (now part of a residential subdivision). Divested land to the east included the footprint of the former Bandiana sewage treatment plant (STP) (now a residential subdivision). Both of these areas were identified as potential off-base PFAS sources.

**ES 4.2 On-base Results**

The results of the sampling completed on-base are summarised within the following table (Table I). The table present an understanding of the scale of the investigation and the number of samples that exceeded screening guidance values for the protection of human health (Human Health Based Guidance Value - HBGV).

**Table I: Results Summary - BMA on Base**

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<tr>
<th>Area</th>
<th>Soil / Sediment</th>
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<th>Groundwater Samples</th>
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<tr>
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<td>Groundwater Samples</td>
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**North Bandiana**

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**East Bandiana**

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**On-base Sensitive Receptors**

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**General Coverage Areas**

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**Notes:**

HBGV – Human Health Base Guidance Value considered applicable to each area’s land use
SA – Source Area
BPS – Bandiana Primary School
BNH – Bandiana Neighbourhood House
SB J in B – South Bandiana, Jack in the Box Creek catchment (i.e. west of topographic divide)
SB KR – South Bandiana, Kiewa River catchment (i.e. east of topographic divide)
NB KR – North Bandiana, Kiewa River catchment
EB KR – East Bandiana, Kiewa River catchment
SB BH – South Bandiana, Bears Hill
**ES 4.3 Off-base Results**

The results of the sampling completed on each of the off-base catchments are summarised within the following table (Table II). The table presents an indication of the scale of the investigation and the number of samples that exceeded screening guidance values for the protection of human health (Human Health Based Guidance Value - HBGV).

**Table II: Off Base Sample Summary**

<table>
<thead>
<tr>
<th>Area</th>
<th>Soil / Sediment</th>
<th>Surface Water</th>
<th>Groundwater Samples</th>
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<tbody>
<tr>
<td></td>
<td>Total Samples</td>
<td>&gt; HBGV</td>
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<td><strong>Off-base Investigations</strong></td>
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<td>KR</td>
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</table>

**Notes:**
- HBGV – Human Health Base Guidance Value considered applicable to each area’s land use
- J in B – Jack in the Box Creek catchment
- WC – Wodonga Creek
- LA SB – Land Adjacent to South Bandiana, where the former tip is located
- LA NB – Land Adjacent to North Bandiana, where the former STP is located
- KR – Kiewa River
- MR – Murray River
ES 5.0 Conceptual Site Model

Development of the CSM has involved consideration of historic site activities involving AFFF containing PFAS (identified as potential sources), and potential migration pathways and exposure routes within the investigation area. The CSM is presented in a graphical cross section (Plate iii).

Plate iii: Conceptual Site Model

ES 5.1 CSM Migration Pathways

Based on the site setting, there is potential for PFAS contamination to migrate via soil/sediment, surface water, groundwater or biota in the Jack in the Box Creek catchment, or the Kiewa River catchment.

The results of the investigations indicated the key CSM pathway for the migration of PFAS off South Bandiana and North Bandiana is via surface water. However, the key migration pathways of PFAS off the base on East Bandiana is likely a combination of surface water and groundwater. Surface water from South Bandiana and North Bandiana flows primarily into the Jack in the Box Creek and then the Wodonga Creek. Surface water and groundwater from East Bandiana flows towards the Kiewa River.

Given the reported low PFAS levels in soils in off-base soils and sediments, wind and atmospheric dispersion of PFAS impacted soils and sediments is not significant pathway for the migration of PFAS from the site.

ES 5.2 CSM Exposure Routes and Receptor Linkages

The human health CSM source-pathway-receptor linkages for the Jack in the Box Creek catchment and the Kiewa River catchment are represented in the flow charts, presented below (Plate iv and Plate v). Some of these linkages are more certain than others – some are considered complete, and others are potentially complete (i.e. the exposure route is not confirmed). For those linkages that are complete, and PFAS concentrations exceed the adopted screening guidance values, there is potential for the PFAS to present an unacceptable risk. In these situations, either additional work will be completed to assess the significance of the potential risk through the Human Health and Ecological Risk Assessment and/or mitigation measures or controls will be introduced to remove or control the potential risk.

The following receptor linkages were not considered to present a risk, as the exposure pathway was either incomplete, or the PFAS concentrations were below the guidance values:
On base Human Health:

- Based on the sampling results within both the source areas and their surrounds on the BMA, and based on the way the land is used, the concentrations of PFAS in the soil are not considered to present a risk.

- On North and South Bandiana, groundwater beneath selected source areas was identified as having PFAS concentrations above the guidance values. However, the water table was generally deep, and groundwater is not extracted. Therefore, the exposure pathway was considered incomplete, and the PFAS in the deeper regional groundwater was not considered to present a risk.

Off base Human Health:

- Water extracted from Wodonga Creek - including that by North East Water for the municipal town supply – is below drinking water guidance values. As such, it is safe to continue to drink the municipal water supply.

- Based on outcomes of other studies conducted in Australia, concentrations of PFAS in water equivalent to the drinking water guidance values were considered safe to use for garden, poultry and stock watering. The Human Health Risk Assessment will provide the mechanism of validating these findings considering the site specific data collected.

The soil, sediment and surface water PFAS concentrations along the majority of the Jack in the Box Creek (including along Arthur Dunstan Park), within Wodonga Creek, and within the main flowing channel of the Kiewa (where swimming and boating occur), were below the guidance values and, based on these current results collected in high flow conditions, it is safe to continue to swim in these areas.
Plate iv: CSM Flow Chart Jack in the Box Creek Catchment
Plate v: CSM Flow Chart Kiewa River Catchment
ES 6.0 Areas of Concern and Future Actions

**ES 6.1 Potential Human Health Risks**

Table III provides a summary of Tier 1 exceedances, the relevant locations, exposure pathways and receptors requiring further assessment or the implementation of management measures. Plate vi provides a spatial illustration of the outcomes of the Tier 1 assessment identifying the areas of concern.

The additional assessments will be completed through the upcoming Human Health and Ecological Risk Assessment (HHERA) process, or recognised as areas requiring monitoring or management within the subsequent PFAS Management Area Plan (PMAP).

**Table III: Tier 1 Human Health Exceedances**

<table>
<thead>
<tr>
<th>Area of Concern</th>
<th>Location</th>
<th>Potential Exposure Pathway</th>
<th>Potential Receptor</th>
<th>Future Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>On-base</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PFAS concentrations in surface water above recreational water guidance values.</td>
<td>Various locations across the base.</td>
<td>Ingestion of water, (incidental).</td>
<td>On-base personnel involved in training and / or maintenance / construction workers.</td>
<td>Apply appropriate health and safety controls during training / maintenance activities.</td>
</tr>
<tr>
<td>PFAS concentrations in groundwater above recreational water guidance values.</td>
<td>Perched groundwater within SA 9 (BH111), and shallow groundwater beneath East Bandiana. (refer to Plate vi – Areas A and B)</td>
<td>Ingestion of water, (incidental).</td>
<td>On-base workers – construction / maintenance when involved in excavation or construction activities which interact with impacted groundwater.</td>
<td>Apply appropriate health and safety controls during maintenance / construction activities.</td>
</tr>
<tr>
<td>Sheep grazing is occurring on selected areas of the base.</td>
<td>North Bandiana and South Bandiana grazing areas. (refer to Plate vi – Areas C and D)</td>
<td>Uptake of PFAS into biota and human exposure via consumption of biota.</td>
<td>Farmers</td>
<td>The level of risk will be the subject of a Human Health Risk Assessment.</td>
</tr>
<tr>
<td><strong>Off-base Jack in the Box Creek Catchment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PFAS concentrations in surface water samples above the</td>
<td>Two samples (SW424, SW463) collected from Jack in the Box Creek immediately</td>
<td>Ingestion of water, (incidental).</td>
<td>Recreational users. Workers – construction / gardeners / maintenance.</td>
<td>The level of risk will be the subject of a Human Health Risk Assessment.</td>
</tr>
</tbody>
</table>
Area of Concern | Location | Potential Exposure Pathway | Potential Receptor | Future Action
--- | --- | --- | --- | ---
recreational water guidance values. | downstream of the base. (refer to Plate vi – Areas E and F) | exposure via consumption of biota. |  |  

**Off-base Kiewa River Catchment**

PFAS concentrations in surface water were above recreational and drinking water guidance values. 
PFAS concentrations in sediments were above the residential soil guidance values.

<table>
<thead>
<tr>
<th>Location</th>
<th>Potential Exposure Pathway</th>
<th>Potential Receptor</th>
<th>Future Action</th>
</tr>
</thead>
</table>
| Oxbow lakes to the east and north-east of East Bandiana, and unnamed creek to the east of North Bandiana. It is known that cattle graze in these areas and there is potential for collection of fish and yabbies from the oxbows and unnamed creek. Hunting of wild deer and duck has been identified in the DSI as occurring within the investigation area. (refer to Plate vi – Areas G) | Uptake of PFAS from surface water and sediments into biota and human exposure via consumption of biota. Ingestion of water: (incidental). | Residents 
Recreational users 
Workers – construction / gardener/ maintenance /farmers. | The level of risk will be the subject of a Human Health Risk Assessment. |

**ES 6.2 Potential Ecological Risks**

Concentrations of PFAS were above the adopted ecological screening guidance values for soil, sediment, and surface water both on-base and off-base Jack in the Box Creek and Kiewa River catchments. It is worth noting that, due to the tendency for PFAS to accumulate in animals and magnify within ecological food chains, the ecological screening guidance values are very low (i.e. close to the laboratory limit of reporting). The level of risk will be the subject of an Ecological Risk Assessment.
ES 7.0 Conclusions

The investigation findings have established a greater understanding of PFAS on and around the BMA, and the following are key conclusions:

- Potential Human Health Risks – On-base:
  - Based on the sampling results within both the source areas and their surrounds on the BMA, and based on the way the land is used, the concentrations of PFAS in the soil are not considered to present a risk.
  - Surface water across the BMA was identified as having PFAS concentrations above the guidance values. However, as people do not swim in or routinely interact with the surface water, exposure is limited and the water is unlikely to present a risk. However, it is important to ensure appropriate health and safety precautions are implemented when people on the base are either involved in maintenance activities, or involved in training which use and/or involve surface water.
  - Within localised areas across North and South Bandiana the groundwater was identified as having PFAS concentrations above the guidance values. However, as the water table is generally deep, and groundwater is not extracted on the base, these impacts are not considered to present a risk. However, within an area localised around the Petroleum, Oils and Lubricants facility (Source Area 9) on South Bandiana and beneath East Bandiana the groundwater is not as deep Therefore, it is important to ensure appropriate health and safety precautions are implemented for construction and maintenance activities which may encounter groundwater in these areas.
Due to the tendency for PFAS to accumulate within plants and animals, further investigation is required to assess if the PFAS identified on the base are accumulating in the sheep grazing on the base. The level of associated with this potentially complete pathway will be the subject of a Human Health Risk Assessment.

Potential Human Health Risks – Off-base:

- Water extracted from Wodonga Creek, including that by North East Water for the municipal town supply, is below drinking water guidance values. As such, it is safe to continue to drink the municipal water supply.
- Based on outcomes of other studies conducted in Australia, concentrations of PFAS in water equivalent to the drinking water guidance values were considered safe to use for garden, poultry and stock watering. The Human Health Risk Assessment will provide the mechanism of validating these findings considering the site specific data collected.
- For recreational uses – the soil, sediment and surface water PFAS concentrations along the majority of the Jack in the Box Creek (including along Arthur Dunstan Park), within Wodonga Creek, and within the main flowing channel of the Kiewa (where swimming and boating occur), were below the guidance values. Based on these current results collected in high flow conditions, it is safe to continue to swim in these areas.
- However, PFAS in surface water sampled in two specific locations within Jack in the Box Creek immediately downstream of the base, and in surface water and sediment in the oxbow lakes to the east of East Bandiana, were higher than the guidance values. The level of risk in these areas will be the subject of a Human Health Risk Assessment.
- Due to the tendency for PFAS to accumulate within plants and animals, further investigation is required to assess if the PFAS identified within the Jack in the Box Creek, Wodonga Creek and Kiewa River are accumulating in the food people are either growing or catching. The level of risk in these areas will be the subject of a Human Health Risk Assessment.

Potential Ecological Risks:

- The concentrations of PFAS in soil, sediment and surface water, both on-base and off-base in both the Jack in the Box Creek and Kiewa River catchments, were higher than the screening values used for identifying potential ecological risk. It is worth noting that, due to the tendency for PFAS to accumulate in animals and magnify within ecological food chains, the ecological screening guidance values are very low (i.e. close to the laboratory reporting limit). The level of risk will be the subject of an Ecological Risk Assessment.

What are the next steps?

- The investigation findings have established a greater understanding of PFAS on and around the BMA, and identified that many of the potential PFAS exposure pathways do not present a risk to people both on and off the base. There is however, in specific areas as described above, the need to undertake further investigation to confirm if an unacceptable human health or ecological risks are present and what management / remedial measures need to be implemented.
- To investigate these risks, the next step that will be undertaken is a Human Health and Ecological Risk Assessment (HHERA) and the development of the PFAS Management Area Plan (PMAP). This process will commence in the second quarter of 2018. The HHERA will involve collecting samples of water, fish and other aquatic biota that people and animals may eat.
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<th>Definition</th>
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<tr>
<td>6:2 FtS</td>
<td>6:2 Fluorotelomer Sulfonic Acid</td>
</tr>
<tr>
<td>ADF</td>
<td>Australian Defence Force</td>
</tr>
<tr>
<td>ADFCC</td>
<td>Australian Defence Force Chaplains College</td>
</tr>
<tr>
<td>AFFF</td>
<td>Aqueous Film Forming Foam</td>
</tr>
<tr>
<td>AST</td>
<td>Aboveground Storage Tank</td>
</tr>
<tr>
<td>AHD</td>
<td>Australian Height Datum</td>
</tr>
<tr>
<td>ALS</td>
<td>Australian Laboratory Services</td>
</tr>
<tr>
<td>AMG</td>
<td>Australian Map Grid</td>
</tr>
<tr>
<td>ANZEC</td>
<td>Australian and New Zealand Environment and Conservation Council</td>
</tr>
<tr>
<td>APHA</td>
<td>American Public Health Association</td>
</tr>
<tr>
<td>ARMCANZ</td>
<td>Agriculture and Resource Management Council of Australia and New Zealand</td>
</tr>
<tr>
<td>ASC NEPM</td>
<td>National Environment Protection (Assessment of Site Contamination) Measure</td>
</tr>
<tr>
<td>ASEM</td>
<td>Army School of Electrical and Mechanical Engineering</td>
</tr>
<tr>
<td>ASH</td>
<td>Army School of Health</td>
</tr>
<tr>
<td>ASLO</td>
<td>Army School of Logistic Operations</td>
</tr>
<tr>
<td>ASLP</td>
<td>Australian Standard Leaching Procedure</td>
</tr>
<tr>
<td>ASO</td>
<td>Army School of Ordnance</td>
</tr>
<tr>
<td>ASoT</td>
<td>Army School of Transport</td>
</tr>
<tr>
<td>ASRIS</td>
<td>Australian Soil Resource Information System</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials</td>
</tr>
<tr>
<td>ATLC</td>
<td>Army Training and Logistics Centre</td>
</tr>
<tr>
<td>AWMA</td>
<td>Albury Wodonga Military Area</td>
</tr>
<tr>
<td>BFFF</td>
<td>Bush fire-fighting foam</td>
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<tr>
<td>BFS</td>
<td>Base Fire Services</td>
</tr>
<tr>
<td>BoM</td>
<td>Bureau of Meteorology</td>
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<td>BMA</td>
<td>Bandiana Military Area</td>
</tr>
<tr>
<td>BSM</td>
<td>Base Services Manager</td>
</tr>
<tr>
<td>BTEXN</td>
<td>Benzene, Toluene, Ethylbenzene, Xylenes and Naphthalene</td>
</tr>
<tr>
<td>bw</td>
<td>Body weight</td>
</tr>
<tr>
<td>CA</td>
<td>Commonwealth Land</td>
</tr>
<tr>
<td>CMS</td>
<td>Contract Maintenance Service</td>
</tr>
<tr>
<td>COC</td>
<td>Chain of Custody</td>
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<td>Contaminants of Potential Concern</td>
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<td>Conceptual Site Model</td>
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<td>Contaminated Site Register</td>
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<tr>
<td>DBYD</td>
<td>Dial Before You Dig Services</td>
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<tr>
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<td>Defence</td>
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<tr>
<td>DELWP</td>
<td>Department of Environment, Land, Water and Planning</td>
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<tr>
<td>DO</td>
<td>Dissolved Oxygen</td>
</tr>
<tr>
<td>DP</td>
<td>Deposited Plan</td>
</tr>
<tr>
<td>DQIs</td>
<td>Data Quality Indicators</td>
</tr>
<tr>
<td>DQOs</td>
<td>Data Quality Objectives</td>
</tr>
<tr>
<td>DSI</td>
<td>Detailed Site Investigation</td>
</tr>
<tr>
<td>EC</td>
<td>Electrical Conductivity</td>
</tr>
<tr>
<td>E&amp;IG</td>
<td>Estate and Infrastructure Group</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
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<tr>
<td>enHealth</td>
<td>Environmental Health Standing Committee of the Australian Health Protection Principal Committee</td>
</tr>
<tr>
<td>EPA</td>
<td>Environment Protection Authority</td>
</tr>
<tr>
<td>EPL</td>
<td>Environment Protection Licence</td>
</tr>
<tr>
<td>ERA</td>
<td>Ecological Risk Assessment</td>
</tr>
<tr>
<td>ESA</td>
<td>Environmental Site Assessment</td>
</tr>
<tr>
<td>ESV</td>
<td>Ecological Screening Value</td>
</tr>
<tr>
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<td>Food Standards Australia New Zealand</td>
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<tr>
<td>GIL</td>
<td>Groundwater Investigation Level</td>
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<td>Golder Associates Pty Ltd</td>
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<tr>
<td>GPR</td>
<td>Ground Penetrating Radar</td>
</tr>
<tr>
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<td>Global Positioning System</td>
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<tr>
<td>GSS</td>
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<tr>
<td>HEPA</td>
<td>Heads of EPAs Australia and New Zealand</td>
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<tr>
<td>HBGV</td>
<td>Human Health Based Guidance Value</td>
</tr>
<tr>
<td>HDPE</td>
<td>High Density Polyethylene</td>
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<tr>
<td>HHERA</td>
<td>Human Health and Ecological Risk Assessment</td>
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</tr>
<tr>
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<td>Joint Logistics Unit, Victoria</td>
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<tr>
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<td>NSW Land and Property Information</td>
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<td>Methyl Blue Activated Substances</td>
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<td>NATA</td>
<td>National Association of Testing Authorities</td>
</tr>
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<td>NDD</td>
<td>Non-destructive Drilling</td>
</tr>
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<td>NEMP</td>
<td>National Environmental Management Plan</td>
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<td>NEPC</td>
<td>National Environment Protection Council</td>
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<td>NEPM</td>
<td>National Environment Protection Measure</td>
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<td>NES</td>
<td>National Environmental Significance</td>
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<td>NHMRC</td>
<td>National Health and Medical Research Council</td>
</tr>
<tr>
<td>NSW</td>
<td>New South Wales</td>
</tr>
<tr>
<td>OCP</td>
<td>Organochlorine Pesticides</td>
</tr>
<tr>
<td>OEH</td>
<td>Office of Environment and Heritage</td>
</tr>
<tr>
<td>OMC</td>
<td>Omeo-Metamorphic Complex</td>
</tr>
<tr>
<td>OPP</td>
<td>Organophosphorus Pesticides</td>
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<tr>
<td>PAH</td>
<td>Polycyclic Aromatic Hydrocarbons</td>
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<tr>
<td>PCB</td>
<td>Polychlorinated Biphenyls</td>
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<tr>
<td>PFAS</td>
<td>Per- and Poly-fluoroalkyl Substances</td>
</tr>
<tr>
<td>PFBA</td>
<td>Perfluorobutanoic acid</td>
</tr>
<tr>
<td>PFBS</td>
<td>Perfluorobutanesulfonic Acid</td>
</tr>
<tr>
<td>PFDA</td>
<td>Perfluorodecanoate</td>
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</table>
PFDoDA  Perfluorododecanoic acid
PFDS  Perfluorodecanesulfonate
PFHpA  Perfluorohexanoic acid
PFHpS  Perfluorohexanesulfonic Acid
PFHxA  Perfluorohexanoic Acid
PFHxS  Perfluorohexane Sulfonic Acid
PFNA  Perfluorononanoate
PFOA  Perfluorooctanoic Acid
PFOS  Perfluorooctane Sulfonate
PFPeA  Perfluoro-<i>n</i>-pentanoic Acid
PFPeS  Perfluoropentanesulfonate
PFUnDA  Perfluoroundecanoic acid
pH  A description of the acidity or alkalinity of a substance
POL  Petroleum, Oils and Lubricants
POP  Persistent Organic Pollutant
PQL  Practical Quantification Limits
PSI  Preliminary Site Investigation
PVC  Polyvinyl Chloride
QA/QC  Quality Assurance / Quality Control
RPD  Relative Percentage Differences
SA  Source Area
SADFO  Senior Australian Defence Force Officer
SAQP  Sampling Analysis and Quality Plan
SEPP  State Environment Protection Policy
SOPs  Standard Operating Procedures
SPR  Source-Pathway-Receptor
STP  Sewage Treatment Plant
SVOC  Semi-Volatile Organic Compounds
SWL  Standing Water Level
TDI  Tolerable Daily Intake
TDS  Total Dissolved Solids
TO  Task Objectives
TOC  Total Organic Carbon
TOF  Total Organic Fluorine
TOPA  Total Oxidisable Precursor Assay
TPH  Total Petroleum Hydrocarbons
TRH  Total Recoverable Hydrocarbons
TWA  Trade Waste Agreements
US EPA  United States Environmental Protection Agency
UST  Underground Storage Tank
VIC  Victoria
VOC  Volatile Organic Compounds
WMIS  Victorian Water Measurement Information System
WUS  Water Use Survey
WQG  Water Quality Guidelines
WWTP  Waste Water Treatment Plant
UNITS

ha  Hectares
Kg  Kilogram
km  Kilometre
L   Litre
L/s Litres per second
m   Metre
m AHD Metres Australian Height Datum
m bgl Metres below ground level
mg/kg Milligrams per kilogram
mg/L  Milligrams per litre
mV  Millivolts
ppm Parts per million
μg/kg Micrograms per kilogram
μg/L  Micrograms per litre
μS/cm Microsiemens per centimetre
°C  Temperature in degrees Celsius
1.0 INTRODUCTION
Golder Associates Pty Ltd (Golder) has been engaged by the Department of Defence (Defence) to undertake a detailed site investigation (DSI) of the nature and extent of Per- and Poly-Fluoroalkyl Substances (PFAS) within and surrounding the Defence Bandiana Military Area (BMA), Victoria.

The BMA is located adjacent to the New South Wales (NSW)-Victorian border town of Wodonga, Victoria on approximately 650 hectares (ha) of land. The BMA is located approximately 3 kilometres (km) from Wodonga town centre and 250 km north-east of Melbourne. The investigation area is presented on Figure 1.

The BMA comprises the following bases:
- Gaza Ridge Barracks (North Bandiana, Victoria)
- Gaza Ridge Barracks (South Bandiana, Victoria)
- Wadsworth Barracks (East Bandiana, Victoria)

The investigation at the BMA is part of a larger program of works as Defence builds its understanding of PFAS contamination across its national estate and assesses potential off-base impacts to surrounding communities and industries.

This DSI presents the results of the initial PFAS source identification stages, the Site Auditor endorsed Sampling Analysis and Quality Plan (SAQP) and the results of the intrusive investigation works.

1.1 Department of Defence PFAS Investigation and Management Program
PFAS are a class of manufactured chemicals that have been used since the 1950s, and due to their unique attributes to make products resist heat, stains, grease and water, they have been used widely. PFAS were used in aqueous film forming foams (AFFF). AFFFs are fire-fighting foams that have been used extensively worldwide, and within Australia, from about the 1970s by both civilian and military authorities. AFFFs were used extensively due to their effectiveness in extinguishing liquid fuel fires.

Older formulations of AFFF contained a number of PFAS that are now known to be persistent in humans and the environment.

As well as fire-fighting foams, PFAS have had many uses in common household and industrial applications. These include stain resistant applications for furniture and carpets, fast food or packaged food containers, cosmetics, personal care products and cleaning products.

Defence has proactively initiated a program of investigations to identify the nature and extent of PFAS on and in the vicinity of some bases. To identify which Defence properties require investigation, Defence completed a risk assessment of facilities based on their historic PFAS use. The work is being done in consultation and communication with Federal and State government agencies as well as community residential and business stakeholders. As part of the Defence PFAS Program, verified assessment test results audited by a third-party Site Auditor / Advisor are made available to the communities, and shared with relevant government agencies to assist with forward planning contamination management, if and as required.
2.0 INVESTIGATION OBJECTIVES

Defence’s primary objective for the program at the BMA is to understand potential contamination risks on both Defence property and surrounding areas, resulting from historical AFFF use. These have been defined by Defence as both Project Key Objectives (KO), being objectives for the whole investigation and communications program, and Task Objectives (TO), being specific to the DSI.

The Project KO identified by Defence include:

1) Conduct a DSI compliant with the National Environmental Protection (Assessment of Site Contamination) Measure (NEPM) 1999, as amended in 2013.
2) Conduct a NEPM compliant Human Health Risk Assessment (HHRA) and Ecological Risk Assessment (ERA) (if assessed as required).
3) Prepare a PFAS Management Area Plan to address identified risks.
4) Develop, maintain and manage site-specific stakeholder information and engagement.

The specific TO include:

1) Undertake a comprehensive assessment of the property and surrounding area to confirm that the on-base and off-base community stakeholders have access to safe drinking water that has not been affected by PFAS contamination.
2) Identify and assess off-base land and water use that may be associated with the human food chain.
3) Identify potential sources of PFAS contamination associated with the former practices, storage and waste management of historical AFFF products on the Defence Estate (i.e. BMA).
4) Identify, confirm and / or characterise the nature and migration potential of PFAS contamination both laterally and vertically to the extent necessary to understand the risk to receptors.
5) Ensure stakeholders are proactively and appropriately informed and engaged through a Community and Stakeholder Engagement Program implemented throughout the investigation.
6) Ensure that all site-specific information is captured and retained for use by Defence.
7) Develop a site-specific PFAS Management Area Plan for the ongoing management of the PFAS contamination.

This DSI primarily addresses KO 1, and presents the preparatory works used to establish the Site Auditor approved SAQP (Golder, 2017), the results of the intrusive investigation and the conceptual site model (CSM). The DSI, including the preparatory works and the SAQP, have been prepared in consideration of specific task objectives TO 1 to TO 4, TO 6 and TO 7. Later stages of the project, for example, risk assessments which may include additional sampling programs, will be required to address KO 2, and support TO 4, or the PFAS Management Area Plan to address KO 3 and TO 7.

Although the focus of the environmental investigation is to identify potential PFAS contamination, as a secondary objective, Defence have an objective to also collect data for non-PFAS contaminants to develop an understanding of the contamination status on or near the property.

This DSI report does not include discussion or interpretation of non-PFAS contaminants of potential concern. The results of the non-PFAS contaminants of potential concern are presented in a separate report.

2.1 Data Quality Objectives

As per Schedule B2 (Guideline on Site Characterisation) of the NEPM "a systematic planning process is used for defining the objectives of a site assessment and to develop a sampling plan for the collection and evaluation of representative data to achieve those objectives. Without systematic planning, the site
assessment may be ambiguous or inconclusive, which may lead to additional sampling requirements, resulting in increased costs and project delays”.

In its simplest form, the planning process outlined in the NEPM should consider:

- The overall objective of the site assessment.
- The decision(s) to be made on the basis of the site assessment findings.
- The constraints on the assessment (financial, time and logistical).
- The degree of flexibility to conduct follow-up investigations.

This project level information can then be used to identify the specific site information needed to address the assessment objectives.

The Data Quality Objectives (DQOs) process is used to define the type, quantity and quality of data needed to support decisions relating to the environmental condition of a site. The seven step DQO / data quality indicator (DQI) process is identified in Schedule B2 of the NEPM as one example of a suitable systematic planning approach for site investigations.

The NEPM DQO process involves the seven steps as follows:

- Step 1: State the problem.
- Step 2: Identify the decision or goal of the investigation.
- Step 3: Identify the information inputs.
- Step 4: Define the site boundaries.
- Step 5: Develop the analytical approach.
- Step 6: Specify performance or acceptance limits.
- Step 7: Develop the plan for obtaining data.

The DQO steps are discussed in detail in Appendix A.

3.0 REGULATORY AND GUIDELINE REQUIREMENTS

The investigations will be completed in accordance with the following regulations and guidelines:

- **Commonwealth (Cth)**
  - Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act, 1999).

- **Victoria (Vic):**
  - Environmental Protection Act 1970 (EP Act, 1970);
  - The State Environment Protection Policy (Groundwaters of Victoria) 1997 (Vic Groundwater SEPP).
The State Environment Protection Policy (Waters of Victoria) 2003 (Vic Surface Water SEPP).

EPA Victoria Publication 1611.3 August 2017, Per- and polyfluorinated alkyl substances (PFAS) Fact sheet.

EPA Victoria Publication 1633.2 August 2017, Incoming water standards for aquatic ecosystem protection: PFOS and PFOA.

EPA Victoria, Managing PFAS-impacted wastes in Victoria, viewed on 6 August 2017.

EPA Victoria Publication 1669 October 2017, Interim Position Statement on PFAS.

Detailed discussion of the abovementioned regulations is presented in Appendix B.

The southern bank of the main channel of the Murray River, forms the boundary between NSW and Victoria\(^4\), and the northern extent of the initial investigation area (Figure 1) currently falls within NSW. As such, the following NSW regulations and guidelines will be considered later in the investigation assessment based on the findings of the investigation:

- **New South Wales (NSW)**
  - NSW Contaminated Land Management Act 1997 (NSW CLM Act, 1997).

In addition, the investigations will be completed in accordance with the following Defence guidance:

- **Department of Defence PFAS Investigation and Management, Detailed Site Investigation Guidance**
  - PFAS TOPA and TOF Analysis Technical Memorandum, Golder Associates (as provided by Defence appointed Specialist Environmental Advisor (Golder) to Defence PFAS Program), dated 4 August 2017.

Guidelines specific to the adopted assessment guidance values (i.e. criteria) are presented in Section 8.0.

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4.0 SCOPE OF WORKS

The investigation program was designed to address KO 1 (Section 2.0) and the DQOs as discussed in Appendix A. The investigation included the following scope of works:

- Identification of potential human and ecological receptors, including the distribution of a WUS to collect information about water supply and use on the properties surrounding BMA.

- An assessment of potential PFAS source areas across BMA which comprised a review of current and historical information such as building layout maps, previous environmental investigation reports and aerial photographs, as well as interviews and site inspections undertaken in July 2017 (Appendix C). The findings of the source assessment are detailed in Section 9.0.

- Development of a SAQP which included:
  - On-base sampling locations from within source areas, in the vicinity of sensitive receptors and to provide general coverage.
  - Off-base sampling locations primarily along surface water systems.
  - Point of use sampling from select properties where domestic or other sensitive use of water was identified via the WUS responses.

- An intrusive investigation in general accordance with the methodologies described in Appendix C and the SAQP (Appendix D) was undertaken between October 2017 and February 2018. The intrusive investigation comprised of the following:
  - 37 surface soil sampling locations, and soil sampling from 39 boreholes, 50 new groundwater monitoring well drilling locations (soil samples were not collected from new off-base monitoring wells with the exception of MW347) and 7 test pits.
  - Sediment and surface water sampling from 152 locations in drainage lines, creeks, rivers, ponds and lakes.
  - Groundwater sampling from 57 new and 25 existing groundwater monitoring wells.
  - Point of use sampling including samples from 1 water supply bore, 3 monitoring bores, 5 tanks, 5 taps, 1 leaking pipe connected to a water supply bore, 3 dams, 8 sediment and surface water locations along an overland flow path and 1 stormwater pit.

- Interpretation of soil, sediment, surface water and groundwater field and analytical results, and review of the results against applicable screening guidance values (Section 9.0). It is noted that this report only presents and interprets PFAS results.

- Development of a CSM to understand the potential for identified human and ecological receptors to be exposed to unacceptable levels of PFAS.

The above mentioned work was done in consultation and communication with Federal and State government agencies as well as community residential and business stakeholders, and will continue to be undertaken. Consultation has included a community information session, discussion of results and provision of letter reports to landowners where sampling was undertaken on private land, and operation of a community hotline and email address.
5.0 GENERAL SITE SETTING

5.1 BMA Description

The BMA is located between Lake Hume and Wodonga in the Murray River Valley, Victoria and comprises the following Defence barracks:

- Gaza Ridge Barracks (North Bandiana, Victoria).
- Gaza Ridge Barracks (South Bandiana, Victoria).
- Wadsworth Barracks (East Bandiana, Victoria).

North, South and East Bandiana straddle the Murray Valley Highway approximately 3 km south-east of Wodonga. The BMA location is shown on Figure 1. The BMA is in a surrounding area that was previously predominantly rural agricultural land, however, is progressively changing to an urban residential area, as the Wodonga Township expands.

General site features are shown on Figure 2. A summary of site information is provided in Table 1.

Table 1: Site Information Summary - Bandiana Military Area

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defence Property ID</td>
<td>0445&lt;br&gt;(0445N) – North Bandiana&lt;br&gt;(0445S) – South Bandiana&lt;br&gt;(0445E) – East Bandiana</td>
</tr>
<tr>
<td>Defence Region</td>
<td>South East Zone</td>
</tr>
<tr>
<td>Street Address</td>
<td>Murray Valley Highway, Bandiana</td>
</tr>
<tr>
<td>Locality</td>
<td>Bandiana</td>
</tr>
<tr>
<td>Municipality</td>
<td>Wodonga City Council</td>
</tr>
<tr>
<td>State</td>
<td>Victoria</td>
</tr>
<tr>
<td>Site Area</td>
<td>650 ha</td>
</tr>
<tr>
<td>Legal Description</td>
<td>North = 2 PS437772, 1&amp;2 TP849697,&lt;br&gt;South = 1,2 &amp; 3 TP849698, 3 PS420756, 2;PS420756 (Bears Hill)&lt;br&gt;East = 1;TP849660, 1;TP139782, 1;TP81825</td>
</tr>
<tr>
<td>Zoning</td>
<td>Commonwealth Land&lt;sup&gt;5&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

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<sup>5</sup> Wodonga Planning Scheme, Amendment C120 – Local Provision, Map No 13, Printed 6/2/2017
5.2 BMA General Operations

Site operations at BMA are undertaken by a number of Defence stakeholders and contractors including:

- **Estate and Infrastructure Group (E&IG)** – providing overall management of the BMA Defence estate.

- **Joint Logistics Unit, Victoria (JLU (V))** – according to Defence JLU (V) is: “primarily a warehousing and maintenance organisation with national and regional logistical support responsibilities for armoured and soft-skinned vehicles, spare parts, loan stores and combat clothing”.

- **Defence Contractors Broadspectrum and Linfox** – contracted by JLU (V) to provide warehousing, and logistics services, armoured vehicle maintenance and services related to the Defence armoured vehicle program.

- **Army Training and Logistics Centre (ATLC)** – provides training to army personnel through six training divisions:
  - Army School of Logistic Operations (ASLO).
  - Army School of Electrical and Mechanical Engineering (ASEME).
  - Army School of Transport (ASoT).
  - Army School of Ordnance (ASO), which includes the Petroleum Platoon based at South Bandiana. The Petroleum Platoon provides fuel handling, dispensing and fire training to Army personnel at South Bandiana facilities.
  - Army School of Health (ASH).
  - Australian Defence Force Chaplains College (ADFCC).

- **The Bandiana Army Museum** – operates the museum on South Bandiana, where warehousing of museum vehicles and equipment and light refurbishment of vehicles occurs.

- **The Contract Maintenance Service (CMS) Contractor** – Spotless Australia Pty Ltd. The CMS is responsible for the management and maintenance of Defence infrastructure, which includes: management of property services, expert estate advice, and performance-based maintenance of fixed plant and equipment, engineering operations, risk management works, and general estate works management.

- **The Garrison Support Service (GSS) Contractor** – Broadspectrum Pty Ltd. Broadly the GSS is responsible for provide support of day-to-day activities including: base security, accommodation management, cafeteria services, cleaning services, firefighting and rescue support services, rations provisioning, grounds maintenance, sporting & recreation services, range and training area management, stores management and waste management, and petroleum, oils, lubricants (POL) and associated support. The fire-fighting and rescue support services, provided by the GSS contractor include the Base Fire Services (BFS), which were historically completed by in house by specialist Army personnel.

BMA is primarily used by Defence for administration, accommodation, training, and warehousing / logistics, however, other operations such as activities related to the storage and maintenance of vehicles including armoured vehicles also occur at the BMA. In addition, North and South Bandiana also include several on-base residential areas for Defence personnel, a community facility on North Bandiana (Bandiana Neighbourhood House), and a Victorian State Government Primary School (Bandiana Primary School) on South Bandiana. The Bandiana Neighbourhood House is a registered child care provider including occasional care, kinder and
playgroup. Sheep grazing is licenced in a portion of South Bandiana along the base of Bears Hill and a portion of North Bandiana to the south-east of the unnamed creek. The grazing licence is held by one grazer. General site operations and site features are presented on Figure 2 and site area land uses on Figure 3.

Based on the above understanding of site operations, it is considered that, in accordance with the NEPM, three land use settings are present across various areas of BMA including Residential (HIL A and HIL B), open space (HIL C) and commercial / industrial (HIL D).

The different land uses are presented on Figure 3. In summary, the following land use settings were applied (further details are outlined in Section):

- Residential (HIL A) for Bandiana Neighbourhood House and Bandiana Primary school.
- Residential (HIL B) for on-base residential areas.
- Open Space (HIL C) for playing fields including the golf course on South Bandiana and areas which are generally undeveloped with little or no infrastructure such as the Close Training Area. There is also potential for grassed parking areas to have dual purposes, hence are also considered open space.
- Commercial / Industrial (HIL D) for workshops, warehouses, office buildings, gymnasiums, hardstand and grassed parking areas, and training areas with infrastructure such as the Petroleum Platoon Fuel Handling and Fire Training areas.

However, it should be noted that some activities or areas on the BMA do not neatly fit within the predefined NEPM land use settings. For example, the Petroleum Platoon Fuel Handling area which contains both hardstand and grassed areas used for training purposes, the dust bowl used for vehicle testing / recovery training and office buildings which are primarily surrounded by grassed areas. These areas do not explicitly fall within the commercial / industrial (HIL D) land use setting which assumes that outdoor areas are predominately covered by hardstand and that opportunities for direct access to soil is minimal. Similarly, the open space (HIL C) land use setting is not entirely appropriate as users are unlikely to spend the majority of their time outdoors and the areas covered by buildings or hardstand is greater than a typical park, playground or playing field. The land use settings adopted for different areas across BMA (and off-base) are further detailed in Section 9.0 which describes the current site operations and features related to the use of AFFF, and presents analytical results.

5.3 BMA General History

The general site history of BMA has been developed based on a number of sources, consistent with the NEPM as considered appropriate for the investigation and DQOs, and include the following:

- The review of historical information and prior environmental reports provided by Defence.
- Interviews completed as part of this investigation, with current and former site personnel with experience on the base ranging from 1960s onwards.
- A review of current and historical building layout plans supplied by Defence.

North, South and East Bandiana were acquired in 1942 as part of the war efforts during World War II, with an estimated 4,000 troops stationed there to operate the facility. At this time, the facility served as a tank, armoured vehicle and equipment workshop as well as containing administration and warehouse facilities.
Vehicle handling included receiving vehicles direct from manufacturers and holding them before issue within Australia or overseas (which continues today). Construction of storage depots and workshops commenced in 1942, with railway tracks from NSW and Victoria also established around this time. The BMA has remained in use as a storage and vehicle processing facility with the addition of Army logistics training.

The North Bandiana Historic Warehouse Precinct, developed during World War II between 1942 and 1945, is recognised as one of Australia’s largest facilities for the storage and processing of technical and motor transport stores (Golder, 2012). Since the early 1960s many of the World War II buildings at the three facilities have been demolished to make way for new constructions such as training, administration and accommodation facilities. Furthermore, from approximately the mid-1990s, portions of the property have been progressively divested. These have included the portions of land now occupied by the adjacent residential estates.

The historic site operations and features related to the use of AFFF are presented in Section 9.0.

### 5.4 Surrounding Land Uses

South, North and East Bandiana are zoned as Commonwealth Land (CA) under the Wodonga City Council Planning Scheme (2017). Commonwealth Land is not controlled by the Planning Scheme; however, a review of the Planning Scheme was undertaken in relation to evaluating surrounding land uses (Figure 3).

A reconnaissance of the surrounding land use and associated uses permitted under the Planning Scheme are as follows:

- **North:** Huon Hill, which is open space used for recreation (e.g. hiking) and farming (i.e. cattle grazing) purposes. The western portion of Huon Hill is identified as Environmental Significance Schedule 2 (Wodonga Hills and Surrounds) in the Planning Scheme. A residential development is located at the base of Huon Hill (adjacent to the western boundary of North Bandiana and to the north of central South Bandiana). It is noted that the Planning Scheme also identifies the area along Kenneth Watson Drive, at the southern base of Huon Hill and directly to the north of North Bandiana, as General Residential Zone 1. This land is currently used for farming, however, is subject to residential development (Development Plan Schedule 10 and 15).

- **East:** Residential properties, including the residential development to the east of north Bandiana (Development Plan Schedule 15 under the Wodonga Planning Schedule) and the Killara Township (Figure 1). The Kiewa River Valley is beyond the residential developments and also adjacent to the south-eastern portion of East Bandiana. The Kiewa River includes a nature reserve which is used for recreation (e.g. hiking and fishing) and is identified as Environmental Significance Schedule 1 (High Quality Agricultural Land). Several rural properties are located adjacent to the eastern boundary of East Bandiana and also on the Kiewa River flood plain, which is used for farming (i.e. cattle grazing) purposes. It is noted that the land at the eastern base and southern base of Huon Hill along Kenneth Watson Drive is subject to Development Plan Schedule 15 under the Wodonga Planning Schedule for residential development. The land is currently used for farming.

- **South:** Bears Hill, which forms a portion of the BMA property, with surrounding rural properties used for cattle grazing (beef) positioned to the south of South Bandiana. A large portion of Bears Hill is identified as Environmental Significance Schedule 2 (Wodonga Hills and Surrounds) in the Planning Scheme. A former Cattle Sales Yard, and prefabricated concrete pipe manufacturing facility are located to the south and south-west of North Bandiana, and to the west of East Bandiana. The land to the south-east of South Bandiana, adjacent to Tooles Road, is currently grazing land, however, the Planning Schedule
identifies the land as Urban Growth Zone 1, indicating that residential development may occur in this area in the future.

- **West**: Wodonga Township, with residential properties located immediately adjacent to the western boundary of South Bandiana (Development Plan Schedule 11 under the Wodonga Planning Schedule). Beyond these, is a mix of commercial, industrial and residential uses associated with the wider Wodonga Township.

5.5 **Previous Environmental Reports**

Reports and documents were provided to Golder by Defence for review as part of the PFAS source assessment. A “Whole of Base” Phase 1 and Phase 2 Environmental Site Assessment of the wider Albury Wodonga Military Area (AWMA) was completed by Golder in 2012 and 2013, this included a comprehensive review of the previous environmental investigations completed at the BMA. With the exception of the GHD Preliminary Sampling Program, completed in 2016, no additional information pertaining to PFAS sampling and analysis was identified in the reports reviewed.

Previous environmental investigations which have made reference to practices and / or incidents providing indications of potential historical AFFF storage, use and disposal across BMA are discussed in the source area review in Section 9.0. The limited historical results available from sampling and analysis for PFAS (or anionic surfactants) undertaken at BMA, including at the Petroleum Platoon Former Fire Training Ground (Section 9.1.1), Current Fire Training Area (Section 9.1.6) and Current Fire Station (Section 9.1.12).

The GHD (2016) preliminary sampling included sampling of three on-base groundwater wells (located on South Bandiana), one off-base bore (located on the far side of the Kiewa River, and three surface water samples at the BMA boundaries. The groundwater monitoring wells sampled reported PFAS concentrations below the laboratory limit of reporting (LOR) (<0.01 μg/L). Two of the three surface water samples reported detectable concentrations of Perfluorooctane Sulfonate (PFOS). The sample collected from a drainage line leading toward Jack in the Box Creek reported 0.5 μg/L, and the sample collected from the drainage discharging from North Bandiana into the unnamed creek discharging towards the Kiewa River reported 0.09 μg/L. The third surface water sample collected from the Kiewa River, upstream of East Bandiana, reported PFAS below the LOR.

Generally, during the site inspections most of the operations on the property appear relatively consistent with those described within Golder (2012), and these were confirmed during the site interviews. The exception was at East Bandiana, where a significant property redevelopment was completed on the central and north-western portions in 2014. Environmental assessment information in terms of supporting investigation reports pertaining to this redevelopment was not established from the reports provided.

6.0 **ENVIRONMENTAL SETTING**

This section provides an understanding of the environmental site setting. The objective of the section is to assist the reader in becoming familiar with the possible contaminant pathways by summarising the site-specific environmental conditions that have the potential to play a role in the distribution and transport of PFAS (where measured and identified) in the environment.

6.1 **General Topography**

The BMA is situated in a landscape known as the Upper Murray, which forms a network of low-lying and relatively flat river and creek floodplains. The plains are scattered by higher rising hills.

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6 Anionic surfactant analysis was completed prior to the availability of PFAS analysis by commercial laboratories, and was used to provide an indication of historic AFFF use.
Huon Hill and Bears Hill are the dominant topographic features within the investigation area (Figure 4). Huon Hill is located in the north-east, rising above 400 m AHD, while Bears Hill is located in the south-west, rising above 350 m AHD.

The BMA is predominantly located in the plain between the two hills, at an elevation ranging between 180 m AHD and 200 m AHD. There is a topographic divide that runs across the BMA in a general north to south alignment. This divides the BMA (South Bandiana) into two catchments (Figure 4). West of the divide, the surface gently slopes in a north-westerly direction, towards the Murray River and Wodonga Creek via Jack in the Box Creek. East of the divide, the surface slopes in an easterly and north-easterly direction, towards the Kiewa River.

6.2 Rainfall

The closest Bureau of Meteorology (BoM) station is located at the Albury Airport (8.5 km north of Wodonga), where monitoring of rainfall commenced in June 1994. The available monthly data are plotted in Plate 1.

![Plate 1: Monthly Rainfall Data](image)

Between 1995 and 2016, the annual rainfall ranged from 297 mm (2006) to 916 mm (2010). The rainfall data are characterised by marked fluctuations, not necessarily affected by seasons. For example, the monthly rainfall that occurred in February 2011 (middle of summer, approximately 267 mm) or in March 2012 (late summer, approximately 255 mm) contributed to about 30 % of the annual rainfall recorded for the corresponding year.

6.3 Wind Speed Direction

To provide an indication of the prevailing regional wind direction, the 2016 wind data collected from the Albury Airport (8.5 km north of Wodonga) sourced from BoM has been plotted in Plate 2. This indicates prevailing wind direction from the west, west north-west and south-east with the strongest wind speeds recorded from...
the west and west north-west. It is noted that the regional wind direction, may be altered on the BMA by the surrounding topographic features.

Plate 2: 2016 Wind Speed and Direction (BoM, Albury Airport)

6.4 Surface Water Systems
6.4.1 Drainage Systems

The BMA is located across two catchment areas, one being the Jack in the Box Creek catchment (west of the topographic divide running across the BMA) and the other one being the Middle Creek / Kiewa River catchment (east of the topographic divide) (Figure 4). The Kiewa River catchment drains to the north and is connected to the broader Murray River catchment.

The surface water across the BMA drains via a complex network of swales and channels within the open areas, and curbs, gutters and underground stormwater pipes within the developed portions of the BMA. The drainage network on the BMA appears to have been developed progressively since the 1940s, and redundant or abandoned infrastructure was evident during the site inspection in portions of the base where large scale demolition has occurred (such as within the Close Training Area [Figure 2]).

It is likely that the pipe and pit drainage network on the BMA would be of variable quality and integrity, dependant on the age of the infrastructure. The recent developments on North and East Bandiana, included significant drainage works, with the installation of an additional stormwater pond (wetlands) on North Bandiana and two large stormwater ponds (settling ponds) on East Bandiana. The surface drainage relevant to each of the identified source areas are discussed further in Section 9.0.

This results in the surface water generated on the BMA to drain into two main directions depending on whether the area is located west or east of the topographic divide (Figure 4):
**West of the topographic divide:**
This part of the BMA includes the western portion of the South Bandiana area. This area drains directly towards a branch of the Murray River, called Wodonga Creek. The dominant drainage in the area is via Jack in the Box Creek (Figure 4). The Jack in the Box Creek runs in a north-north-westerly direction, from the north-west portion of the BMA to Wodonga Creek (3.5 km away from the BMA).

Jack in the Box Creek is an intermittent surface watercourse, with variable sections being constructed along its course before discharging to Wodonga Creek. Further upstream, the creek is connected by gullies and shallow drainage channels that are running across the western-most portion of the BMA. The gullies are inferred to reflect ephemeral drainages originating from Bears Hill that have been variably modified by human activity. The gullies and drainage channels are typically dry and were generally observed to have pools of surface water during and following heavy rain. It was however noted that a small pond along one of the major drainage lines leaving South Bandiana consistently contained water (Photograph 1). The small pond is located approximately 60 m from the north-western boundary of South Bandiana (sample location SD/SW463 on Figure 6A) within Jack Perry Reserve and was observed to contain a yabbie trap. It is understood that the pond is a permanent water feature.

**East of the topographic divide:**
This part of the BMA includes the remainder and largest portion of the property. This area drains towards the Kiewa River, which in turn drains towards the Murray River. The dominant drainage in the area is Middle Creek, which runs in a north-east direction along the south-eastern edge of the investigation area (Figure 4). Middle Creek discharges into the Kiewa River along the eastern-most portion of East Bandiana. Middle Creek is a permanent surface watercourse.

*Photograph 1: Small pond along drainage channel leading to Jack in the Box Creek*

*Photograph 2: Unnamed creek discharging from North Bandiana underneath Whytes Road and towards the residential estate to the east.*
The other dominant surface watercourse is an unnamed creek (Figure 4) that runs north of Middle Creek, broadly parallel to its course and discharging to the Kiewa River about 2.1 km north of the confluence with Middle Creek. The unnamed creek is also a permanent surface watercourse, which has been modified by the construction of ponds and channelised portions (Photograph 2). The unnamed creek originates in the eastern portion of South Bandiana as a number of drainage channels which discharge to a series of stormwater ponds (wetlands) located at the entry to South Bandiana. The stormwater ponds (wetlands) subsequently discharge to the unnamed creek which flows through North Bandiana to the north-east (towards Whytes Road). Portions of the unnamed creek within North Bandiana have been concreted. A yabbie trap was observed along the unnamed creek where the creek flows underneath Whytes Road. The course of the creek is still being actively modified, mainly to accommodate new residential development in the portion immediately downstream of North Bandiana. Aerial imagery and site inspections identified modification of the unnamed creek including reducing the bank gradient and channel widening, presumably to accommodate increased stormwater runoff attributed to the increased hardstand surfaces (Photograph 3).

The Kiewa River, where the water from this part of the BMA eventually drains, has a meandering course, with a succession of small billabongs and secondary branches. This indicates that the river is a geomorphologically active zone, with active erosion, transport and deposition of sediments occurring. Through observations made during the investigation, it was evident that water flows through the upper portions of the drainage network were variable, and within many of the drainage lines observed to be dry during the sampling program. It was observed that many of these drainage features would only carry water during rain events. Permanent water was only observed within the larger surface water features on the BMA such as lined ponds, dams or stormwater ponds (wetlands or settling ponds). More consistent flows were observed within the lower portions of the drainage catchments off the base, such as within Middle Creek, and the lower reach of Jack in the Box Creek. However, several small features were observed to also have permanent or semi-permanent water in close proximity to the BMA, including ponds on Jack in the Box Creek immediately down-gradient of the BMA, and at the point where the unnamed creek exits the BMA at Whytes Road. The lower portions of the drainage networks are also expected to be influenced by the seasonal flow patterns observed within the major rivers within the region (Section 6.4.2)

The BMA sewerage network is described in Section 9.3.1, as this has been identified as a potential diffuse source of PFAS.

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7 Nearmap imagery dated 13 June 2017, 10 October 2017 and 20 January 2018.
6.4.2 River Flows

The Kiewa River originates on the Bogong High Plains and flows north to its confluence with the Murray River. The river is considered to be an unregulated system with no major dams or weir structures to regulate the supply or extraction of water for consumptive use. The storages operated for hydroelectric power generation in the high country are reported to have only a minor influence on the natural flow regime of the Kiewa River (Goulburn-Murray Water, 2017). The average annual flow out of the Kiewa River catchment is approximately 788,700 ML/year.

The flow regime of the Kiewa River displays considerable seasonal variation, with the months of August to October generally exhibiting the highest flows following snow melt in the high country (Plate 3). Water levels in the Kiewa River during sediment and surface water sampling in early October 2017 were in the order of 2.5 m\(^8\), in comparison to water levels of approximately 1.5 m during the site inspection in July 2017 as well as in mid to late November. Water levels in the Murray River, both at the Albury Union Bridge gauging station (409001) and Doctors Point gauging station (409017), appear to exhibit a similar trend with generally higher water levels between the months of August and October.

The water levels measured during surface water sampling on the Kiewa River ranged between 0.8 and 2.5 m, with an average depth of 1.8 m (Table A). The water levels measured during sampling in the Murray River ranged between 1.2 and 3.8 m, and 1.3 and 2.9 m in Wodonga Creek.

![Daily Kiewa River water levels from 2007 to 2017](image)

Plate 3: Daily Kiewa River water levels from 2007 to 2017 (data from the Kiewa River gauge station 402222).

It is also noted that the water levels in the Kiewa River appear to be very responsive to significant rainfall events (Plate 4). For example, following approximately 80 mm of rainfall recorded at Albury Airport weather

Relative to the river bed at the sampling location.
station (72160) over 2 and 3 December 2017, the Kiewa River rose from approximately 1.3 m to a maximum of 2.9 m.

A combination of elevated river levels following the seasonal snow melt, the responsiveness of the Kiewa River to rainfall and the unregulated nature of the Kiewa River, assist in recharging numerous oxbow lakes and secondary channels across the floodplain, and result in flooding primarily along the lower reaches of the Kiewa River. Figure 5 shows the area along the lower Kiewa River subject to flooding based on the 1 in 100 Australian Rainfall Index (ARI)\textsuperscript{9}. The eastern bank of the Kiewa River appears more susceptible to flooding.

![Graph showing river levels and rainfall comparison](image)

**Plate 4: Water levels in the Kiewa River during 2017 in comparison to rainfall.**

### 6.4.3 Geomorphology

The BMA is located in a semi-confined valley formed by Huon’s Hill to the north and Bears Hill to the south. As discussed above in Section 6.3, the BMA drains via minor creeks and drainage channels to the north-west to Jack in the Box Creek, or to the east to the Kiewa River.

Alluvium (2017) conducted a desktop review of long-term sediment deposition zones within the investigation area. It was reported that Jack in the Box Creek, a highly modified system, has limited potential to adjust laterally due to surrounding urbanisation and as such there are limited opportunities for the development of depositional zones and associated features such as bars, benches or old channel courses (Alluvium, 2017). It is therefore likely that the creek is subject to scour and erosion during larger rainfall events. Alluvium (2017) reported that depositional zones may be found in backwater areas behind culverts and potentially in the flood-out zone near the confluence of Wodonga Creek. It is further noted that Jack in the Box Creek has been diverted into a large stormwater pipe from Thomas Mitchell Drive, Wodonga to Murray Valley Highway. The

\textsuperscript{9} Flood data obtained from the Victorian Department of Sustainability and Environment.
stormwater pipe network generally travels beneath Arthur Dunstan Park and Holloway Park. The parks themselves appear to have been reshaped and used to provide an overland flow path during major flood events.

The Kiewa River, and one of its main tributaries Middle Creek, is a largely unmodified river system with an extensive floodplain. Alluvium (2017) reported that the Kiewa River is a partly confined meandering river with the floodplain containing multiple fluvial landforms such as oxbow lakes, flood runners and anabranches which become active during flood events. During flood events, these landforms receive and retain water and sediment (particularly fine-grained sediments, which are easily suspended and transported). It was noted that fluvial landforms with riparian vegetation, higher elevations which are less prone to scour and minimal impact from urbanisation are likely to provide the best environments for long-term sediment deposition (Alluvium, 2017).

While the Kiewa River is largely unmodified, the drainage channel exiting North Bandiana at Whytes Road and flowing through a residential estate to the east and into the Kiewa River has undergone significant changes due to recent urbanisation. During the site walkover, it was observed that considerable earthworks have been undertaken to reshape the channel including flattening the bank gradient and widening the channel base. This has assumedly been undertaken to increase channel capacity due to the increase in hardstand surfaces associated with urbanisation which results in higher volumes of surface water runoff and to improve the aesthetic appeal of the channel.

6.4.4 Surface Water Quality Parameter Results

The surface water sampling locations for Jack in the Box Creek and Wodonga Creek are identified on Figure 6A and for the Kiewa River and Murray River on Figure 6B. The surface water quality parameters as well as other observations recorded during sampling are included in Table A and are discussed below and presented according to the respective drainage catchments, including:

- On-base Drainage.
- Jack in the Box Creek.
- Wodonga Creek.
- Kiewa River including Middle Creek and Unnamed Creek.
- Murray River.

**On-base Drainage**

Surface water samples were collected from on-base drainage including stormwater drainage channels, ponds and dams between October and December 2017. During the investigation drainage channels were often observed as dry and as a result, samples were not able to be collected from 48 proposed locations. From the 43 locations where surface water samples were able to be collected, 38 were stagnant with flowing water observed at two sample locations downstream of the outlet for the stormwater ponds (wetlands) at the entrance to South Bandiana (0445S_SW356 and 0445S_SW357), two sample locations along the unnamed creek on North Bandiana (0445N_SW368 and 0445N_SW370), and along a concrete lined drainage channel on North Bandiana (0445N_SW366). The water column depths for 34 samples were equal to or less than 0.5 m, with a maximum water depth of 3.2 m recorded in the stormwater ponds (wetlands) at the entrance to South Bandiana (0445S_SW347).

The samples collected were generally described as low to medium turbidity, with no odour and pale brown in colour. The following notable observations were recorded:
An unknown sheen was observed at sample location 0045S_SW305 (Source Area 2 – Base Fire Services – Former Fire Training Ground, Figure 6A).

A blue sheen and surface foam was noted at sample location 0445S_SW336 (Source Area 6 – Current Fire Training Area, Figure 6A).

Slight foaming was observed at sample location 0445S_SW332 (South Bandiana: Drainage to Jack in the Box Creek, Figure 6A).

A potentially organic sheen was observed at sample location 0445N_SW447 (North Bandiana: Kiewa River catchment, Figure 6B).

A slight hydrocarbon odour was noted at sample location 0445N_SW374 (North Bandiana: Kiewa River catchment, Figure 6B).

A hydrocarbon sheen was observed at sample location 0445E_SW381 and 0445E_SW388 (East Bandiana: Kiewa River catchment, Figure 6B).

The average, maximum and minimum surface water quality parameters recorded from on-base surface water samples are summarised in Table 2. The pH recorded generally indicated slightly acidic to neutral conditions for most locations. The most acidic sample was collected from the pond within the Current Fire Training Area (0445S_SW336) (Source Area 6, Section 9.1.6). The electrical conductivity (EC) and total dissolved solids (TDS) generally indicated fresh to very slightly brackish surface water present across the BMA. The two highest EC values recorded were 478 micro Siemens per centimetre (µS/cm) from the concrete pond within the Former Base Fire Services Training Area and 777 µS/cm from the pond within the Current Fire Training Area (0445S_SW336) (Source Area 2 and 6, Sections 9.1.2 and 9.1.6). The redox potential ranged between 219 and 430 mV indicating mildly to moderately reducing surface water environments.

<table>
<thead>
<tr>
<th>Drainage Catchment</th>
<th>Value</th>
<th>pH (pH units)</th>
<th>EC (µS/cm)</th>
<th>Eh (mV)</th>
<th>Temp (°C)</th>
<th>DO (ppm)</th>
<th>TDS (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-Base Max</td>
<td>9.95</td>
<td>777</td>
<td>430.4</td>
<td>28.3</td>
<td>14.77</td>
<td>363.35</td>
<td></td>
</tr>
<tr>
<td>On-Base Min</td>
<td>5.03</td>
<td>19.69</td>
<td>218.7</td>
<td>13.2</td>
<td>0.0</td>
<td>13.6</td>
<td></td>
</tr>
<tr>
<td>On-Base Av</td>
<td>6.86</td>
<td>122.64</td>
<td>337.21</td>
<td>20.11</td>
<td>4.30</td>
<td>77.36</td>
<td></td>
</tr>
</tbody>
</table>

**Jack in the Box Creek**

Surface water samples were collected from along Jack in the Box Creek, including from stormwater pits where the creek has been diverted into pipes. A total of 14 surface water samples were collected, including two samples at location 0445_SW424 prior to and following a small rain event. One proposed sampling location (0445_SW423) was dry. The sampling locations were generally observed to be flowing and water column depth increased downstream towards Wodonga Creek. The samples collected were generally described as low to medium turbidity, with no odour and pale brown in colour.

The average, maximum and minimum surface water quality parameters recorded from surface water samples collected along Jack in the Box Creek are summarised in Table 3. The pH of surface water samples collected ranged between 5.44 and 8.07 pH units indicating slightly acidic to slight alkaline conditions. The EC and TDS recorded generally indicated fresh water for surface water samples collected along Jack in the Box Creek. The
redox potential ranged between 251 and 441 mV indicating mildly to moderately reducing surface water environments.

Table 3: Summary Surface Water Quality Parameters for Jack in the Box Creek

<table>
<thead>
<tr>
<th>Drainage Catchment</th>
<th>Value</th>
<th>pH (pH units)</th>
<th>EC (µS/cm)</th>
<th>Eh (mV)</th>
<th>Temp (°C)</th>
<th>DO (ppm)</th>
<th>TDS (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jack in the Box Creek</td>
<td>Max</td>
<td>8.07</td>
<td>505.00</td>
<td>440.60</td>
<td>19.90</td>
<td>9.86</td>
<td>105.95</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>5.44</td>
<td>41.80</td>
<td>250.70</td>
<td>14.50</td>
<td>1.62</td>
<td>33.80</td>
</tr>
<tr>
<td></td>
<td>Av</td>
<td>6.45</td>
<td>119.73</td>
<td>369.47</td>
<td>16.67</td>
<td>5.89</td>
<td>68.31</td>
</tr>
</tbody>
</table>

**Wodonga Creek**

Surface water was collected from four locations along Wodonga Creek, upstream and downstream of the Jack in the Box Creek confluence. Three surface water samples were collected from locations 0445_SW436 and 0445_SW437 to assess variability in the vertical water column. The samples collected were generally described as low turbidity, with no odour and clear in colour.

The average, maximum and minimum surface water quality parameters recorded are summarised in Table 4. The water quality parameters recorded were generally consistent across the sample locations and depths, and indicate slightly acidic, fresh and mildly to moderately reducing environments. The high DO values are representative of the swiftly flowing water observed.

Table 4: Summary Surface Water Quality Parameters for Wodonga Creek

<table>
<thead>
<tr>
<th>Drainage Catchment</th>
<th>Value</th>
<th>pH (pH units)</th>
<th>EC (µS/cm)</th>
<th>Eh (mV)</th>
<th>Temp (°C)</th>
<th>DO (ppm)</th>
<th>TDS (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wodonga Creek</td>
<td>Max</td>
<td>5.74</td>
<td>44.50</td>
<td>414.00</td>
<td>13.40</td>
<td>10.59</td>
<td>178.75</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>5.34</td>
<td>31.30</td>
<td>370.80</td>
<td>11.80</td>
<td>8.60</td>
<td>27.95</td>
</tr>
<tr>
<td></td>
<td>Av</td>
<td>5.48</td>
<td>35.45</td>
<td>386.76</td>
<td>12.46</td>
<td>9.49</td>
<td>52.37</td>
</tr>
</tbody>
</table>

**Kiewa River including Middle Creek and Unnamed Creek**

Surface water samples were collected from within the Kiewa River channel (11 locations), oxbow lakes on the Kiewa River floodplain (11 locations) and Middle Creek (three locations). The samples collected from within the Kiewa River and Middle Creek were generally described as low turbidity, with no odour and clear. The samples collected from within oxbow lakes on the Kiewa River floodplain were generally described as low turbidity, with no odour and pale brown in colour. Surface water samples from the unnamed creek were collected from within the residential estate to the east of North Bandiana and across the floodplain to the confluence with the Kiewa River. Surface water samples were collected from nine locations, including four locations from the portion of the unnamed creek which traverses the floodplain. The samples collected were generally described as low to medium turbidity, with no odour and pale brown in colour.

The average, maximum and minimum surface water quality parameters recorded are summarised in Table 5. The water quality parameters recorded for pH and redox potential were generally consistent across the
sample locations from within the Kiewa River and oxbow lakes. The pH of surface water samples collected ranged between 5.16 and 8.29 pH units indicating slightly acidic to slight alkaline conditions. The redox potential ranged between 118 and 428.9 mV indicating mildly to moderately reducing surface water environments.

The water quality parameters recorded for EC and TDS indicated fresh water conditions, however, EC was generally higher for samples collected from oxbow lakes.

The DO values ranged from 0.14 ppm to 11.01 ppm. Dissolved oxygen values were generally higher for samples collected from within the Kiewa River, representative of the swiftly flowing water observed, compared to samples collected from the stagnant oxbow lakes.

**Table 5: Summary Surface Water Quality Parameters for the Kiewa River**

<table>
<thead>
<tr>
<th>Drainage Catchment</th>
<th>Value</th>
<th>pH (pH units)</th>
<th>EC (µS/cm)</th>
<th>Eh (mV)</th>
<th>Temp (°C)</th>
<th>DO (ppm)</th>
<th>TDS (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kiewa River &amp; Middle Creek (in channel)</td>
<td>Max</td>
<td>7.32</td>
<td>29.10</td>
<td>388.70</td>
<td>16.60</td>
<td>11.01</td>
<td>22.10</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>5.28</td>
<td>19.00</td>
<td>290.80</td>
<td>13.60</td>
<td>8.86</td>
<td>15.60</td>
</tr>
<tr>
<td></td>
<td>Av</td>
<td>6.02</td>
<td>25.16</td>
<td>368.40</td>
<td>14.42</td>
<td>10.37</td>
<td>17.88</td>
</tr>
<tr>
<td>Unnamed Creek</td>
<td>Max</td>
<td>8.29</td>
<td>532.00</td>
<td>375.00</td>
<td>25.70</td>
<td>8.32</td>
<td>345.80</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>6.58</td>
<td>71.90</td>
<td>118.00</td>
<td>17.90</td>
<td>0.14</td>
<td>90.55</td>
</tr>
<tr>
<td></td>
<td>Av</td>
<td>7.65</td>
<td>250.99</td>
<td>286.47</td>
<td>20.59</td>
<td>3.85</td>
<td>178.16</td>
</tr>
<tr>
<td>Oxbow Lakes</td>
<td>Max</td>
<td>7.89</td>
<td>573.00</td>
<td>428.90</td>
<td>25.30</td>
<td>10.67</td>
<td>435.00</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>5.63</td>
<td>56.70</td>
<td>268.00</td>
<td>14.10</td>
<td>2.24</td>
<td>45.50</td>
</tr>
<tr>
<td></td>
<td>Av</td>
<td>6.53</td>
<td>255.15</td>
<td>365.40</td>
<td>18.58</td>
<td>5.68</td>
<td>208.13</td>
</tr>
</tbody>
</table>

**Murray River**

Five surface water samples were collected from the Murray River between Lake Hume and slightly downstream of the Kiewa River confluence. The samples collected from within the Murray River were generally described as low turbidity, with no odour and clear.

The average, maximum and minimum surface water quality parameters recorded are summarised in Table 6. The water quality parameters recorded were generally consistent across the sample locations and indicate neutral, fresh and mildly to moderately reducing environments, except for a notably high redox potential of 1,026 mV at sample location 0445_SW420. The high DO values are representative of the swiftly flowing water observed.
### Table 6: Summary Surface Water Quality Parameters for the Murray River

<table>
<thead>
<tr>
<th>Drainage Catchment</th>
<th>Value</th>
<th>pH (pH units)</th>
<th>EC (µS/cm)</th>
<th>Eh (mV)</th>
<th>Temp (°C)</th>
<th>DO (ppm)</th>
<th>TDS (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Murray River</td>
<td>Max</td>
<td>7.52</td>
<td>73.80</td>
<td>1,026.00</td>
<td>20.20</td>
<td>11.29</td>
<td>52.65</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>7.18</td>
<td>40.60</td>
<td>283.80</td>
<td>14.60</td>
<td>7.86</td>
<td>31.20</td>
</tr>
<tr>
<td></td>
<td>Av</td>
<td>7.31</td>
<td>49.66</td>
<td>448.18</td>
<td>16.42</td>
<td>10.42</td>
<td>38.58</td>
</tr>
</tbody>
</table>

### 6.4.5 Sediments

The sediment sampling locations for Jack in the Box Creek and Wodonga Creek are identified on Figure 6A and for the Kiewa River and Murray River on Figure 6B. Sediment sample descriptions including analysis of particle size and total organic carbon (TOC) are discussed below and presented according to the respective drainage catchments, including:

- **On-base Drainage.**
- **Jack in the Box Creek.**
- **Wodonga Creek.**
- **Kiewa River including Middle Creek.**
- **Murray River.**

The sediment sample descriptions as well as other observations recorded during sampling are included in Table B. Analytical results for particle size distribution and TOC are presented in Tables G and K.

#### On-Base Drainage

Sediment samples were collected from on-base drainage including stormwater drainage channels, stormwater ponds (wetlands and settling ponds) and dams between October and December 2017. During the investigation, a total of 85 on-base sediment samples were collected. Samples were not able to be collected at 5 locations as some ponds were lined (concrete or rubber). Sediment samples collected from ponds or dams were generally described as silts or clays, while the soil conditions along drainage lines was considerably more variable (Table 2).

Total organic carbon analysis was undertaken at select locations across on-base sampling locations. The TOC values were highly variable across the BMA, ranging between 1,400 mg/kg (0445S_SD348) from a sample collected from a pond on the golf course, to 65,800 mg/kg (0445S_SD356) from a sample along a drainage channel below the outlet of the stormwater ponds (wetlands) at the entrance to South Bandiana. However, it is noted that the overall average TOC is similar across the various drainage features sampled (Table 7).

#### Table 7: Summary Total Organic Carbon (mg/kg) for on-base sediment sample

<table>
<thead>
<tr>
<th>TOC Values</th>
<th>Drainage Channels (incl earthen bunds)</th>
<th>Ponds / Dams</th>
<th>Unnamed Creeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max</td>
<td>65,800</td>
<td>58,300</td>
<td>42,700</td>
</tr>
<tr>
<td>Min</td>
<td>2,300</td>
<td>1,400</td>
<td>2,800</td>
</tr>
<tr>
<td>Average</td>
<td>18,718</td>
<td>20,525</td>
<td>18,117</td>
</tr>
</tbody>
</table>
Jack in the Box Creek

A total of 12 sediment samples were collected along Jack in the Box Creek, including two samples at location 0445_SW424 prior to and following a small rain event. Sediment samples were not able to be collected from two proposed stormwater pit sampling locations (0445_SD428 and 04445_SD429). The sediment samples generally varied between sands, silts and clays. Sample locations near areas of higher flow, such as SD427 where the creek is diverted into pipes and SD433 and SD434 near the Wodonga Creek confluence, generally exhibited coarser grained sediments.

Total organic carbon for the samples analysed ranged between 1,700 (mg/kg) in sample 0445_SD426 to 45,300 mg/kg in sample 0445_SD431. Higher TOC was generally observed in samples with finer grained sediments.

Wodonga Creek

Sediment was collected from four locations along Wodonga Creek, upstream and downstream of the Jack in the Box Creek confluence. Three sediment samples were collected from locations 0445_SW436 and 0445_SD437 to assess variability in sediment with increased depth. The samples collected were generally described as primarily containing gravel and sand, with the exception of sample location 0445_SD437 which was described as primarily containing clay.

Total organic carbon for the samples analysed ranged between 1,200 (mg/kg) in sample 0445_SD436 at 0.9 m to 10,300 mg/kg in sample 0445_SD435 at 0.0 m. There appears to be little correlation between TOC and depth, however, samples with finer grained sediments (i.e. clays and silts) appear to have a higher TOC in comparison to samples containing primarily coarse grained soils.

Kiewa River including Middle Creek and Unnamed Creek

Sediment samples were collected from within the Kiewa River channel and its tributaries (i.e. Middle Creek and the Unnamed Creek flowing from North Bandiana through a residential estate to the east) and oxbow lakes on the Kiewa River floodplain. The samples collected from within the Kiewa River channel and Middle Creek were generally described as fine to medium grained sand or silty sand. The samples collected from within oxbow lakes were generally described as silty clay or clay, usually dark grey or dark brown in colour, with organic matter including roots and leaves.

The differences in sample descriptions between in channel and oxbow lake samples are reflected in the Particle Size and TOC analysis undertaken (Tables B and K). It is noted that TOC was generally considerably higher in samples collected from oxbow lakes compared to samples collected from within the river channel (Table 8).

Table 8: Summary Total Organic Carbon (mg/kg) for Kiewa River sediment samples

<table>
<thead>
<tr>
<th>TOC Summary Values</th>
<th>Kiewa River channel and tributaries</th>
<th>Oxbow Lakes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max</td>
<td>24,300</td>
<td>68,400</td>
</tr>
<tr>
<td>Min</td>
<td>11,000</td>
<td>24,900</td>
</tr>
<tr>
<td>Average</td>
<td>16,333</td>
<td>43,764</td>
</tr>
</tbody>
</table>
**Murray River**

Five sediment samples were collected from the Murray River between Lake Hume and slightly downstream of the Kiewa River confluence. The samples collected were generally described as sand or gravelly sand, ranging from fine to coarse grained.

Total organic carbon for the samples analysed ranged between 1,000 (mg/kg) in sample 0445_SD421 to 12,400 mg/kg in sample 0445_SD419.

### 6.5 Geology

#### 6.5.1 Geological History

A summary of the geological history of the investigation area is presented here based on the ‘1:50,000 Albury Geological Map Sheet’ (1979) and ‘Geology of Victoria’ (2003). The geological history consists of a description of how the geological units formed over time and how their formation has influenced their composition and structure (i.e. their stratigraphy) as well as their spatial distribution across the investigation area.

Three main geological units have formed the subsurface. The relationship between these geological units is presented in Plate 5 from older (below) to younger (above):

- The **Omeo-Metamorphic Complex** (OMC) forms the basement rock to the investigation area.

- The OMC is formed by predominantly fine sediments and muds transported during the Ordovician period from an ancient continental zone and deposited at the margin of a nearby ocean. In the subsequent Silurian period, these layers of sediments were then subjected to tectonic activity (i.e. folding and faulting), which also resulted in these layers to be perforated by intrusions of magmatic rock, mainly granite. The tectonic compression converted the sediments into rocks. Typically, the clays and muds formed schist, while the granite typically transformed into gneiss.

- A long geological hiatus between the Silurian and Tertiary periods resulted in weathering and erosion of these rocks over a period of about 300 million years. The hills of the investigation area are the remnants of this period i.e. Bears Hill (gneiss) and Huon Hill (schist) (Figure 2).

- The **Shepparton Formation** resulted from deposition and erosion of sand, silt and clay associated with the ancient Murray River system during the Tertiary period. Erosion caused by this ancient river system resulted in the carving of a deep palaeovalley within the basement rock (OMC), causing the bottom of the valley to be about 100 m lower that the current creek levels. Further erosion of the hills resulted in the further accumulation of sediments at the base of the hills (i.e. foothill deposits) which is called the **Shepparton Colluvium**. This unit is inferred to be mainly distributed along the central part of the investigation area between Bears Hill and Huon Hill (Figure 2). The ancient Murray River system also resulted in the deposition of alluvial sediments within...
the palaeovalley. These sediments are called the *Shepparton Fluvium* and are inferred to be mainly distributed in the north-west and the south-east portions of the investigation area, reflecting old terraces of old surface water courses. The sediments of the Shepparton Fluvium contain the preserved sandy deposits of the old meandering river channels, which are commonly called “shoestring sands”. The later part the Tertiary period was also marked by tropical temperatures and high humidity, which resulted in the development of a lateritic weathering profile, causing iron staining and iron rich horizons as well as orange to red mottling.

- The *Coonambigdal Formation* also resulted from river sediment deposition and erosion. The unit formed during the Quaternary period. The *Coonambigdal Colluvium* resulted from more recent erosion of the hills, supporting the distribution of these sediments along the foothills of Huon and Bears Hills (Figure 2). The *Coonambigdal Fluvium* resulted from sediment deposition, with these sediments being predominantly distributed in the lower lying area of the investigation area, along the existing creeks and rivers (Murray River, Kiewa River, Wodonga Creek and Middle Creek [Figure 1]). The Coonambigdal Fluvium is also likely to contain some shoestring sands. These sediments are typically grey in colour as there has been limited weathering since the Quaternary.

More recently (late Quaternary), flooding of the Murray and Kiewa Rivers has resulted in the deposition of organic rich silt and clay (i.e. floodplain silts). In the past 150 years, human activities modified the landscape, resulting in a degree of modification of the natural topography.

### 6.5.2 Site Geology

The geological profiles described in the borehole logs from the investigation are generally consistent with the geological units identified on the Geological Map Sheet (1979) which are described in Section 6.5.1. The borehole logs are presented in Appendix F and drilling locations are identified on Figures 7A and 7B.

**South Bandiana**

The sub-surface conditions encountered across South Bandiana are generally consistent with the unconsolidated hill-wash deposits (Quaternary and Tertiary colluvial deposits comprising sands, silts, clays and gravels) inferred by the Geological Map Sheet (1979). The Quaternary and Tertiary Shepparton Colluvium was encountered across South Bandiana and along the upper portion of Jack in the Box Creek. The Shepparton Colluvium was generally observed to comprise fine grained red brown sediments (clays and silts) with some interbedded sands and gravels.

Omeo-Metamorphic Complex (OMC) basement rock, in the form of granite, was identified towards the base of Bears Hill (South Bandiana). The depth to basement rock generally decreased towards Bears Hill as did the thickness of the overlying Shepparton Colluvium and Coonambigdal Colluvium.

Granite was encountered at MW317 within Source Area 2 in the western portion of South Bandiana, and in MW322 within Source Area 7 in the central portion of South Bandiana at approximately 32 m bgl (approximately 172 m AHD). Source areas are described in Section 9.0. Granite was also encountered at MW336 at approximately 36 m bgl (approximately 170 m AHD). The granite was overlain by material representative of the Coonambigdal Colluvium at both MW322 and MW336, while at MW317, granite was overlain by material representative of the Coonambigdal Colluvium from surface to approximately 15 m bgl, and Shepparton Colluvium from approximately 15 m bgl to 32 m bgl. The Coonambigdal Colluvium was generally observed to comprise brown and grey sandy clays with inclusions of mica and biotite.

Residual soils (or highly to extremely weathered granite) were observed in MW315 and MW318 which were drilled in the vicinity of MW317, however, consolidated bedrock was not identified. Residual soils or bedrock were not identified at MW316 located approximately 180 m to the north of MW317 which was advanced to
37 m bgl (approximately 158 m AHD) or at MW320 located approximately 160 m north of MW322 which was advanced to 32 m bgl (approximately 161 m AHD).

Granite was encountered at 1 m bgl (approximately 217 m AHD) in MW362 drilled at the base of Bears Hill in the vicinity of bedrock outcrops.

**North Bandiana**

The 1:50,000 Albury Geological Map Sheet (1979) suggests that North Bandiana is situated across the Quaternary and Tertiary Shepparton Colluvium, and the younger Shepparton Fluvium.

Investigation indicated that the geological profiles across the northern and western portion of North Bandiana generally comprised fine grained red brown sediments (clays and silts) with some interbedded sands representative of the Shepparton Colluvium. Bedrock or residual soils were not encountered on North Bandiana. It is noted that the maximum extent of drilling was 25 m bgl (approximately 165 m AHD) at MW339. The geological profiles in the southern portion of North Bandiana, along the unnamed creek where the topographic gradient is considerably flatter, exhibited an increase in coarser grained soils (i.e. sands and gravels) and were generally described as brown, orange brown and grey brown. These soils are considered to be representative of the Shepparton Fluvium.

**East Bandiana**

The 1:50,000 Albury Geological Map Sheet (1979) suggests that the East Bandiana site is situated across the older Quaternary Shepparton Fluvium and the younger Quaternary Coonambigdal Fluvium. The geological profiles encountered during the investigation were various combinations of clays, silts and sands, which is reflective of the nature of the depositional environment (i.e. fluvial). The upper 3 to 5 m of the profile tended to be dominated by brown sandy soils, underlain by brown clay dominated soils. The soils encountered on East Bandiana are likely representative of the Shepparton Fluvium given that the soils encountered along the Kiewa River were generally coarser and the lower-lying areas of the current flood plain to the east of East Bandiana are more likely to comprise the Coonambigdal Fluvium. However, distinguishing between the two geological units is difficult as they relate to similar depositional environments.

6.6 **Groundwater**

6.6.1 **Aquifer (Groundwater) Units**

Multiple aquifer units were recognised within the vertical profile at the investigation area during the prior investigations. Based on prior investigation work, Table 9 summarises the characteristics of these units and their possible roles in the movement of groundwater while Plate 6 illustrates the generalised relationship between the units. Aquifers are units that have a propensity to transmit groundwater flow, acting as groundwater flow pathways. Aquitards are units that have a propensity to provide a barrier to groundwater flow, restricting and therefore modifying the movement of groundwater.
Table 9: Main Aquifer Units

<table>
<thead>
<tr>
<th>Age</th>
<th>Aquifer Units</th>
<th>Description</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tertiary</td>
<td>Shepparton Fluvium</td>
<td>Old alluvial terraces with red-brown sediments. Variable lithology with clay, silt and sand. Presence of well-developed shoestring sands, increasing with depth.</td>
<td>Porous medium. Aquifer (where there is shoestring sands) interbedded with aquitards of clay and silt. Unconfined aquifer unit.</td>
</tr>
<tr>
<td>Ordovician</td>
<td>Omeo-Metamorphic Complex</td>
<td>Folded and faulted schist and gneiss, forming the regional basement rock to the younger sedimentary formations</td>
<td>Fractured rock medium. Aquitard (where there is schist). Localised aquifer (where the gneiss is fractured). Unconfined in the hills, confined in the river valleys.</td>
</tr>
</tbody>
</table>

The nature of the aquifer units distributed in the investigation area was variable, reflecting the diversity of geological processes that have resulted in their emplacement (e.g. erosion, transport, deposition and weathering).
Plate 6: Conceptual Hydrogeological Cross-section

The investigation work confirmed that the primary aquifer units of the investigation area were the Shepparton Fluvium and Colluvium and, to a lesser extent, the Coonambigdal Fluvium, with locally well-developed network of shoestring sands acting as the main paths of least resistance for groundwater flow. Bores installed within these units are known to have moderate yield (up to 5 L/s) (GSV, 1974).

The underlying basement rocks of the OMC are known to have a generally low hydraulic conductivity (i.e. measure of propensity to transmit groundwater). Bores that have been drilled in the basement rock have reported limited yield (usually less than 1 L/s) while a number of bores are known to have been abandoned due to limited supplies (GSV, 1974).

6.6.2 Depth to Groundwater

The depth to groundwater below ground surface is included in Table C and are shown on Figure 8C.

The depth to groundwater across the bases is summarised as follows:

- **South Bandiana** – water levels generally ranged between approximately 10 to 15 metres below ground surface (mbgs) across the northern portion of South Bandiana, and gradually deepened up to 40.6 mbgs to the south towards Bears Hill. Groundwater was significantly shallower in MW362 (approx. 5.4 mbgs) installed at the base of Bears Hill within the OMC. Perched groundwater was observed in BH111 (approx. 2.9 mbgs) located in Source Area 9 in the northern, central portion of South Bandiana.

- **North Bandiana** – water levels ranged between approximately 1.8 to 3.8 mbgs along the unnamed creek and eastern boundary of North Bandiana where groundwater wells were installed in the Shepparton Fluvium. Groundwater gradually deepened up to 14.7 mbgs to the north and west in wells installed in the Shepparton Colluvium, towards Huon Hill.

- **East Bandiana** – water levels ranged between approximately 5 mbgs near the eastern boundary of East Bandiana to approximately 7 mbgs near the western boundary.
6.6.3 Groundwater Flow

Groundwater wells were installed and gauged across the BMA to supplement the existing BMA groundwater monitoring network and along the main drainage lines (Jack in the Box Creek and Kiewa River) within the off-base investigation area. The groundwater wells gauged, including water levels, survey data and screen intervals are provided in Table C. The well construction logs are included in Appendix F.

A total of 85 groundwater monitoring wells were gauged, including 44 wells on South Bandiana (four of which were dry), eight wells on North Bandiana, 23 wells on East Bandiana and 10 wells located off-base. The standing water levels (SWLs) measured across the bases are summarised as follows:

- **South Bandiana** – water levels ranged between 157.514 m AHD in MW305 near the north-western boundary which was installed within the Shepparton Colluvium to 212.319 m AHD in MW362 at the base of Bear’s Hill which was installed within the OMC. The SWLs observed across South Bandiana varied considerably which, in part reflects the change in topography from approximately 175 m AHD in the north of the base, to approximately 220 m AHD at the base of Bear’s Hill in the south of the base.

- **North Bandiana** – water levels ranged between 164.046 m AHD in MW345 located along the unnamed creek which was installed in the Shepparton Fluvium to 174.942 m AHD in MW339 located along the western boundary of the base which was installed within the Shepparton Colluvium.

- **East Bandiana** – water levels in wells screened in the shallow zone ranged between 158.610 m AHD in MW20 to 160.540 m AHD in MW06-A located at the current fire station along the western boundary of the base. Water levels in wells screened in the intermediate and deep zones ranged between 157.970 m AHD in MW21 to 160.159 m AHD in MW350(D) located at the current fire station.

**Water Table Groundwater Flow**

The groundwater levels and inferred groundwater contours for the water table groundwater are shown on Figure 8A. The geological formation in which each groundwater well is screened is included in Table C.

The groundwater elevation data indicates that there is a groundwater divide which occurs through central South Bandiana. West of the divide (i.e. the western portion of South Bandiana) groundwater flow is generally towards the north-west towards Wodonga Creek, and east of the divide (i.e. the eastern portion of South Bandiana, North Bandiana and East Bandiana) groundwater flow is towards the north-east towards the Kiewa River. The considerably larger area draining towards the Kiewa River and the difference in groundwater levels from the central portion of South Bandiana to East Bandiana indicates that the Kiewa River is likely to act as a regional groundwater discharge zone. This is consistent with the groundwater contours as shown on the ‘Wangaratta 1:250,000 Hydrogeological Map Sheet’.

The groundwater levels and contouring indicate the following with respect to groundwater flow:

- Groundwater flows within the western portion of South Bandiana appear to be dominated by Bears Hill and Huon Hill. Groundwater generally flows to the north to north-west from the base of Bears Hill through the Close Training Area and generally towards Jack in the Box Creek, and to the south from the base of Huon Hill.

- The groundwater divide appears to be generally consistent with topography and appears to be influenced considerably by Bears Hill and Huon Hill. Immediately west of the divide (i.e. in the central portion of South Bandiana between Bears Hill and Huon Hill), groundwater appears to initially flow to the west prior to assimilating with the overall north-westerly flow direction towards Jack in the Box Creek.

- There is some uncertainty relating to the position of the groundwater divide due to the lack of groundwater data in the eastern portion of South Bandiana (i.e. to the east of MW337).
Similar to South Bandiana, groundwater flow on North Bandiana is influenced by the topography of Huon Hill. Groundwater on North Bandiana generally appears to flow to the south-east within the northern portion situated on the Shepparton Colluvium, before slightly re-orientating more towards the east and the Kiewa River where the base transitions to Shepparton Fluvium and topography becomes gentler. Groundwater flow across East Bandiana is generally towards the east to north-east, towards the Kiewa River.

As expected, the SWLs along Jack in the Box Creek decrease in a downstream direction from 159.701 m AHD in MW302 to 151.486 m AHD in MW361. Similarly, SWLs in the groundwater wells along the Kiewa River decrease from 155.712 m AHD in MW356 to 151.986 m AHD in MW358.

Groundwater elevation data from MW305, MW317 and MW01 were excluded from contouring as the elevations were considered anomalous in relation to elevation data obtained from other nearby groundwater wells. Groundwater wells installed at considerably deeper depths within the same geological formation (including MW306, MW328, MW350 (D), MW21, MW30, MW42, MW43, MW47 and MW46) and groundwater wells installed in perched water (including BH111) were also excluded from contouring.

**Intermediate and Deep Groundwater Flow**

Groundwater contours for intermediate and deep groundwater have not been generated due to the limited number of wells targeting these zones. Groundwater elevation data for wells considered to be screened within intermediate or deep zones are included on Figure 8B. The geological formation in which each groundwater well is screened is included in Table C.

Two deeper groundwater wells (MW306 and MW328) were installed on South Bandiana. It is noted that these wells were installed within the same geological formation (Shepparton Colluvium) as nearby shallow (water table) wells.

MW306 is screened approximately 5 to 10 m deeper relative to nearby groundwater wells (MW305, MW307 and MW308) and MW328 is screened approximately 10 to 12 m deeper relative to nearby groundwater wells (MW326 and MW327). The groundwater levels observed in both MW306 and MW328 are similar to nearby wells, however, the groundwater chemistry (including cation and anion composition and concentrations, and EC) varies relative to nearby wells (Section 6.6.6). The groundwater levels within the intermediate and deep groundwater wells across East Bandiana (MW350 (D), MW21, MW30, MW42, MW43, MW46, and MW47) were generally similar to the shallow groundwater wells, indicating a general connectedness between the three zones.

**6.6.4 Groundwater Discharge**

Surface water interacts with groundwater as follows:

- **Losing stream:** A losing stream is a section of a surface water course that recharges the groundwater flow system. This occurs when the surface water levels are higher than the surrounding groundwater levels. When the surface water course is permanent, it takes place on a permanent basis. When the surface water course is intermittent, it happens on an intermittent basis.
  - The topographic levels indicate that the surface water courses running through the BMA are expected to act predominantly as losing streams. This includes Middle Creek and theUnnamed Creek in the most eastern part of the BMA.
  - The presence of losing streams means that impacted surface water has the potential to contaminate groundwater. This is more likely to be the case where the alluvial sediments underneath the surface water course are coarser and more permeable, which is typically the case in the deeper parts of the catchments (i.e. further down the valleys).
- **Gaining stream**: A gaining stream is a section of a surface water course that acts as a groundwater discharge zone (i.e. groundwater flows into surface water). The topographic levels indicate that the surface water courses in the deeper parts of the catchments (i.e. down the valleys) are expected to be gaining, including:
  - In the Jack in the Box Creek Catchment as follows: Wodonga Creek and possibly the most downstream section of Jack in the Box Creek;
  - In the Kiewa River Catchment as follows: The Kiewa River and associated Oxbow lakes.

Surface water courses can transition from gaining to losing streams during periods of increased surface water runoff. The groundwater wells located in areas where it is considered possible that groundwater is discharging to surface water have been identified in Table 10. The groundwater wells are generally located immediately up-gradient of a potential receiving surface water bodies, have shallow water levels and were installed in predominantly sandy soils. These wells are also identified as the most appropriate to assess groundwater quality potentially discharging to a surface water body, because they are the closest wells to surface water receptors between potential sources and those receptors.

Table 10: Groundwater wells where groundwater is likely to be discharging to surface water

<table>
<thead>
<tr>
<th>Groundwater Well ID</th>
<th>Water Level (mbgs)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>On-Base</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MW345</td>
<td>3.36</td>
<td>Located on the bank of the unnamed creek on North Bandiana, approximately 15 m from the creek.</td>
</tr>
<tr>
<td>MW346</td>
<td>1.78</td>
<td>Located on the bank of the unnamed creek on North Bandiana, approximately 30 m from the creek.</td>
</tr>
<tr>
<td>MW351</td>
<td>4.75</td>
<td>Located on the eastern boundary of East Bandiana, approximately 150 m up-gradient from a large off-base oxbow.</td>
</tr>
<tr>
<td>MW352</td>
<td>4.68</td>
<td>Located on the eastern boundary of East Bandiana, approximately 90 m up-gradient from a large off-base oxbow.</td>
</tr>
<tr>
<td>MW16</td>
<td>6.41</td>
<td>Located on the eastern boundary of East Bandiana, approximately 210 m up-gradient from an off-base oxbow.</td>
</tr>
<tr>
<td>MW35</td>
<td>6.47</td>
<td>Located on the eastern boundary of East Bandiana, approximately 195 m up-gradient from an off-base oxbow.</td>
</tr>
<tr>
<td>MW34</td>
<td>6.95</td>
<td>Located on the eastern boundary of East Bandiana, approximately 140 m up-gradient from an off-base oxbow.</td>
</tr>
<tr>
<td>MW46</td>
<td>7.46</td>
<td>Located on the eastern boundary of East Bandiana, approximately 140 m up-gradient from an off-base oxbow.</td>
</tr>
<tr>
<td>MW47</td>
<td>6.96</td>
<td>Located on the eastern boundary of East Bandiana, approximately 140 m up-gradient from an off-base oxbow.</td>
</tr>
<tr>
<td>Groundwater Well ID</td>
<td>Water Level (mbgs)</td>
<td>Comments</td>
</tr>
<tr>
<td>--------------------</td>
<td>-------------------</td>
<td>----------</td>
</tr>
<tr>
<td><strong>On-Base</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MW20</td>
<td>5.96</td>
<td>Located on the eastern boundary of East Bandiana, approximately 90 m up-gradient from an off-base oxbow.</td>
</tr>
<tr>
<td>MW21</td>
<td>6.57</td>
<td>Located on the eastern boundary of East Bandiana, approximately 90 m up-gradient from an off-base oxbow.</td>
</tr>
<tr>
<td>MW18</td>
<td>5.88</td>
<td>Located on the eastern boundary of East Bandiana, approximately 40 m up-gradient from an off-base oxbow.</td>
</tr>
<tr>
<td>MW354</td>
<td>6.31</td>
<td>Located on the south-eastern boundary of East Bandiana, approximately 155 m up-gradient from an off-base oxbow and 65 m up-gradient of a drainage channel which flows directly to the Kiewa River floodplain oxbows.</td>
</tr>
<tr>
<td>MW29</td>
<td>7.26</td>
<td>Located on the southern boundary of East Bandiana, approximately 40 m up-gradient of a drainage channel which flows directly to the Kiewa River floodplain oxbows.</td>
</tr>
<tr>
<td>MW30</td>
<td>7.35</td>
<td>Located on the southern boundary of East Bandiana, approximately 40 m up-gradient of a drainage channel which flows directly to the Kiewa River floodplain oxbows.</td>
</tr>
<tr>
<td><strong>Off-Base</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MW361</td>
<td>2.42</td>
<td>Located on the bank of Jack in the Box Creek, approximately 15 m from the creek.</td>
</tr>
<tr>
<td>MW356</td>
<td>0.42</td>
<td>Located on the bank of the Kiewa River, approximately 15 m from the river.</td>
</tr>
<tr>
<td>MW357</td>
<td>1.31</td>
<td>Located at the confluence of the unnamed creek and Kiewa River. Approximately 15 m from the unnamed creek and 30 m from the Kiewa River.</td>
</tr>
<tr>
<td>MW358</td>
<td>2.11</td>
<td>Located on the bank of the Kiewa River, approximately 20 m from the river.</td>
</tr>
</tbody>
</table>

**6.6.5 Hydraulic Conductivity**

Hydraulic conductivity testing of 13 groundwater monitoring wells was undertaken as per the methodologies described in Appendix C.

The results of the tests are summarised in Table 11 below with the outputs presented in Appendix G. The field sheets including well details and size of slug used in each well are also included in Appendix G.
Table 11: Summary Hydraulic Conductivity Results

<table>
<thead>
<tr>
<th>Well ID</th>
<th>Aquifer</th>
<th>Estimated Hydraulic Conductivity (m/s)</th>
<th>Solution Method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Falling Head</td>
<td>Rising Head</td>
</tr>
<tr>
<td>MW301</td>
<td>Shepparton Colluvium</td>
<td>1.1E-09</td>
<td>-</td>
</tr>
<tr>
<td>MW306</td>
<td>Shepparton Colluvium</td>
<td>9.8E-08</td>
<td>-</td>
</tr>
<tr>
<td>MW309</td>
<td>Shepparton Colluvium</td>
<td>*</td>
<td>6.4E-08</td>
</tr>
<tr>
<td>MW319</td>
<td>Shepparton Colluvium / Weathered</td>
<td>*</td>
<td>2.1E-07</td>
</tr>
<tr>
<td></td>
<td>OMC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MW326</td>
<td>Shepparton Colluvium</td>
<td>5.9E-10</td>
<td>-</td>
</tr>
<tr>
<td>MW344</td>
<td>Shepparton Fluvium</td>
<td>7.7E-07</td>
<td>5.9E-07</td>
</tr>
<tr>
<td>MW346</td>
<td>Shepparton Fluvium</td>
<td>8.0E-07</td>
<td>4.3E-07</td>
</tr>
<tr>
<td>MW352</td>
<td>Shepparton Fluvium</td>
<td>9.2E-06</td>
<td>9.8E-06</td>
</tr>
<tr>
<td>MW354</td>
<td>Shepparton Fluvium</td>
<td>8.4E-07</td>
<td>-</td>
</tr>
<tr>
<td>MW356</td>
<td>Coonambigdal Fluvium</td>
<td>1.0E-03</td>
<td>*</td>
</tr>
<tr>
<td>MW357</td>
<td>Coonambigdal Fluvium</td>
<td>1.7E-04</td>
<td>1.5E-04</td>
</tr>
<tr>
<td>MW360</td>
<td>Shepparton Fluvium</td>
<td>1.2E-06</td>
<td>*</td>
</tr>
<tr>
<td>MW362</td>
<td>Omeo-Metamorphic Complex</td>
<td>5.9E-10</td>
<td>-</td>
</tr>
</tbody>
</table>

Notes:
- Slow recovery, water level not stabilised after falling head test
* Test not used due to unreliable data

KGS: Kansas Geological Survey

6.6.6 Groundwater Quality Parameter Results

The physio-chemical parameters measured during groundwater sampling are included in Table D and summarised in the sections below. The groundwater well development records and groundwater sampling records are included in Appendix H and Appendix I, respectively.
Electrical Conductivity

Electrical conductivity (EC) was highly variable across the investigation area, ranging from 67.1 µS/cm at MW356 located along the Kiewa River to 15,514 µS/cm at MW310 located in the western portion of South Bandiana.

It was generally observed that groundwater wells screened within the Shepparton Colluvium had the highest electrical conductivities and would be considered slightly brackish to brackish. Groundwater wells installed in the Coonambigdal Fluvium along the Kiewa River and in the Shepparton Fluvium on East Bandiana generally exhibited the lowest conductivities and are considered fresh.

pH

The pH recorded during groundwater sampling generally ranged between 5.18 pH units in MW331 located in the central portion of South Bandiana and 7.62 pH units in MW360 located along Jack in the Box Creek. The pH recorded generally indicated that groundwater is slightly acidic to neutral. Anomalous pH readings were recorded in MW310 (8.02), MW316 (11.95), MW327 (11.80) and MW362 (9.68). These readings are considered to be anomalous based on the pH recorded at nearby wells screened within the same formation which were generally slightly acidic to neutral. It is noted that the pH was confirmed with an alternate water quality meter and the water quality meter was bump tested.

Oxidation Reduction Potential

The oxidation reduction potential ranged from 124.8 mV in MW323 located in the central portion of South Bandiana to 373.7 mV in MW42 located near the eastern boundary of East Bandiana. The oxidation reduction potentials generally indicate mildly to moderately reducing groundwater conditions.

Dissolved Oxygen

Dissolved oxygen recorded during groundwater sampling generally ranged between 0.00 ppm in MW328 located in the central portion of South Bandiana and 5.02 ppm in BH11 located in the central portion of South Bandiana. The DO concentrations recorded indicate that groundwater varied between poorly oxygenated (<1 ppm) to well oxygenated (>5 ppm).

A number of anomalous DO readings were recorded including 7.59 ppm (MW329), 9.90 ppm (MW325), 6.99 ppm (SMW08) and 5.63 ppm (MW314). These readings are considered to be anomalous based on the DO values recorded at nearby wells screened within the same formation, and as DO within groundwater is generally less than 5 ppm.

Temperature

The groundwater temperatures recorded ranged between 16.0 °C in MW361 along Jack in the Box Creek to 23.8 °C in MW12 located in the central portion of East Bandiana.

Major Ion Composition

The concentrations of major cations (chloride, sulphate and bicarbonate) and anions (calcium, magnesium, sodium and potassium) were analysed in all on-base groundwater samples collected. The analytical results are included in Table I and presented in the piper plot below (Plate 7).

The analytical results indicate considerable differences in groundwater chemistry between the groundwater wells installed in the Shepparton Colluvium and Shepparton Fluvium. The shallow groundwater wells installed within the Shepparton Colluvium are representative of groundwater dominated by sodium and chloride, with minor elements of calcium, sulphate and bicarbonate. It is noted that groundwater wells installed deeper within the Shepparton Colluvium (e.g. MW306 and MW328) generally exhibit similar groundwater chemistry,
however, the proportion of bicarbonate to sodium and chloride tends to be higher, and overall concentrations of major cations and anions are lower.

The Shepparton Fluvium is generally dominated by bicarbonate, with minor elements of sodium, magnesium and chloride. There appears to be no considerable difference in groundwater chemistry between the shallow, intermediate and deep groundwater wells.

Plate 7: Piper plot for on-base groundwater wells, where wells have been categorised based on geological formation, depth and base.

6.6.7 Groundwater Classification

The VIC Groundwater SEPP (1997) classifies groundwater into five segments (A1, A2, B, C and D) on the basis of background salinity (TDS) levels with each segment having defined beneficial uses for protection (Appendix B). Segment A1 is classified as having the lowest TDS ranging between 0 and 500 mg/L, up to Segment D which is classified as TDS greater than 13,000 mg/L.

Based on a review of the Department of Natural Resources (DNRE, 1995) “Victorian Groundwater Beneficial Use Map Series, South Western Victoria Water Table Aquifers” the groundwater quality of the BMA is classified as Segment B with a TDS range of 1,001 to 3,500 mg/L.
Based on the water quality parameters recorded during groundwater sampling (Table D), it is considered that the groundwater quality within the investigation area is classified as both Segment A1 / A2 and Segment B. The segments of each groundwater catchment are discussed below:

- **Jack in the Box Creek:**
  - The background well installed at the base of Bears Hill (MW362) within the OMC reported a TDS of 984 mg/L which would be classified as Segment A2. It is noted that the VIC Groundwater SEPP (1997) states that groundwater is classified on the basis of the background level of TDS.
  - The remaining on-base wells and wells within the upper Jack in the Box Creek catchment are predominately installed within the Shepparton Colluvium and can generally be classified as Segment B. It is however noted that localised areas, particularly the north-western corner of South Bandiana, observed TDS concentrations greater than Segment B (up to 10,084 mg/L at MW310). There were also a small number of wells installed within weathered OMC or Shepparton Colluvium towards the base of Bears Hill where TDS concentrations were lower and would be classified as Segment A2. However, fresh water was introduced during the drilling method and this may have contributed to the lower than expected TDS concentrations (Section 10.3.2).
  - The two wells installed in the lower Jack in the Box Creek groundwater catchment within the Shepparton Fluvium, MW360 and MW361, are classified as Segment A2 and Segment A1 respectively.

- **Kiewa River catchment:**
  - Similar to the Jack in the Box Creek catchment, the groundwater wells installed within the Shepparton Colluvium on South Bandiana, and North Bandiana where groundwater was observed in the Shepparton Colluvium or towards the transitional zone from Shepparton Colluvium to Shepparton Fluvium, can generally be classified as Segment B.
  - The groundwater wells installed on East Bandiana where groundwater was generally observed in the Shepparton Fluvium, and the Kiewa River floodplains where groundwater was observed in the Coonambigdal Fluvium, can generally be classified as Segment A1.
  - It is noted that a background well was not installed within the Kiewa River catchment.

Based on the TDS, it is evident that both the upper Jack in the Box Creek and Kiewa River groundwater catchments are classified as Segment B, while the lower catchments with sandier soils are classified as Segment A1. The primary difference between Segment A1 / A2 and B is that Segment A1 / A2 identifies potable water supply as a beneficial use.

The classification of groundwater within the investigation area as Segment A1 / A2 is considered appropriate given the following:

- The VIC Groundwater SEPP (1997) states that groundwater is classified on the basis of the background level of TDS (i.e. Segment A2 for Jack in the Box Creek);
- There is no evidence that the groundwater wells screened within different geological units are separate;
- Low concentrations of TDS within sandy soils; and
- The presence of groundwater bores (registered and un-registered) used for domestic purposes within both catchments.
It is however noted that in some portions of the investigation area, particularly on North and South Bandiana, where hydraulic conductivity is low, and TDS is high, the classification of groundwater as Segment A1/A2 is considered conservative.

7.0 POTENTIAL RECEIVERS

The potential receptors which may be exposed to PFAS both on-base and off-base within the investigation area were considered based on observations and information received during the site inspection and intrusive investigation, a review of available information such as land use data and water extraction licences, and distribution of the WUS. The key information sources including water extraction and the WUS survey are discussed below, followed by identification of the potential receptors.

7.1 Surface Water and Groundwater Extraction

Water extracted from the Kiewa River is primarily for irrigation purposes, with 140 irrigation licences issued along the length of the Kiewa allowing licence holders to extract a maximum total allocation of approximately 11,500 ML/yr (Goulburn-Murray Water, 2017). The investigation understands from information provided by Goulburn-Murray Water that there are no licenced off-takers in the Kiewa River within the Investigation Area, although the presence of unlicensed offtake cannot be excluded.

Water is extracted from Wodonga Creek by North East Water for treatment and distribution to Wodonga and the surrounding townships of Kiewa, Tanangbalanga, Bandiana, Baranduda, Bonegilla, Ebdon, Killara, Barnawartha, Chiltern and Springhurst (NEW, 2012). It is understood that North East Water has a River Murray Bulk Entitlement (WSE000143) which allows extraction of 9,187.6 ML/yr and a maximum extraction rate of up to 71 ML/day (DELWP, 2017). A total of 6,604 ML was extracted by North East Water during 2016-17 from the Wodonga Creek off-take (NEW, 2017). In addition to the off-take by North East Water, information provided by Goulburn-Murray Water indicated there are a small number of licenced extractors in the Wodonga Creek.

Goulburn-Murray Water indicate there is no licenced off-take from Jack in the Box Creek.

A search of the Victorian government bore registration database (Visualising Victoria’s Groundwater and Victorian Water Management Information System) identified eight domestic stock bores, three irrigation bores and one commercial bore (Appendix J). The registered groundwater bores are identified on Figure 1. The following is noted:

- Six of the domestic stock bores and all three irrigation bores are located to the north-west of South Bandiana, within the Jack in the Creek catchment area. These bores are generally considered to be down-gradient of South Bandiana. The closest of these bores (WRK951070) is located approximately 500 m north-west of the South Bandiana boundary. This bore is 180 m in depth and screened in granite bedrock.

- Two domestic stock bores and the one commercial bore are located to the south to south-west of Bears Hill. These bores are generally considered to be up-gradient of South Bandiana.

7.2 Water Use Survey

As part of the investigation, Golder facilitated the distribution of a Water Use Survey (WUS). The WUS was designed to collect information about water supply and use on the properties surrounding the BMA. Each of the chosen survey distribution areas are shown on Figures 9A and 9B.

In general, the surrounding properties at which it was considered necessary to understand water use are those which fall within close proximity to BMA, or are located down-gradient of BMA, and therefore have the...
potential to be within the transport pathway of either surface water and / or groundwater discharges from the BMA.

In addition to the WUS, Golder obtained spatial data from North East Water on the reticulated water supply network infrastructure over the investigation area. This information was used to supplement the understanding of water use provided by the WUS.

This rationale for the selection of the WUS footprint was presented to the Defence appointed Site Auditor, Mr Phillip Bayne of Jacobs (as summarised in Golder 2017). Jacobs subsequently indicated agreement with the proposed distribution area to inform the investigation planning.

**WUS Distribution**

A total of 2,161 WUS were distributed to properties within the distribution area via a mailbox drop that occurred in the first and second week of August 2017.

The WUS distribution areas associated with the BMA include:

- **Jack in the Box Creek WUS Area (Area 1 – Figure 9a)** – within this area, the nominated properties included those which generally fall within the Jack in the Box Creek catchment or are located in close proximity to the northern boundary of South Bandiana and North Bandiana. Within this area, properties identified as having a registered groundwater bore, were also approached directly via door knocking.

- **South Bandiana WUS Area (Area 2– Figure 9a)** – within this area, the nominated properties included those which are positioned close to the southern and south-eastern boundaries of South and North Bandiana, and fall within a portion of the Middle Creek catchment.

- **North Bandiana WUS Area (Area 4 – Figure 9a)** – within this area, the nominated properties included those which generally fall within the catchment of the unnamed creek which passes through North Bandiana. The properties which are located to the north-western boundary of North Bandiana have also been included.

- **Kiewa River WUS Area (Area 3 – Figure 9a)** – within this area, the nominated properties included those which are positioned within the Kiewa River flood plain located to the south, east and north-east of the three Bandiana Defence properties. As the groundwater flow within the alluvial flood plain deposits is likely to be highly complex the flood plain catchment positioned north of East Bandiana and a portion to the south was included to identify potential receptors. A low response rate was recorded for the area of Killara, following the initial distribution period, subsequently the area was targeted for a second distribution via a mailbox drop.

The WUS survey was not distributed to the southern side of Bears Hill as the site inspection and interviews indicated low potential for the use and / or storage of AFFF up-gradient of this area. This was confirmed by the results of preliminary sampling undertaken during the site inspection phase to assess the presence / absence of PFAS in detectable concentrations (Section 9.3.5).

The distribution of the WUS in the residential estate to the west of North Bandiana (Area 4, Figure 9A) was limited to the properties adjacent to the boundary of North Bandiana, as the properties are located up-gradient of both North and South Bandiana, and there were no reports of AFFF use or storage in the western portion of North Bandiana.

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On-Property Water Use

Water use on the base was discussed with relevant Defence identified persons during the site interviews, including representatives from the Defence E&IG Group, the CMS and other personnel who were involved in the property maintenance and development from the 1970s onwards. It was reported that no water extraction bores were currently or historically used on the base. All water supply was reported by personnel interviewed as being sourced from the reticulated water supply system operated by North East Water. Mains water was noted as being used for swimming pools, training activities, irrigation and two stock watering points, one on South Bandiana and one on North Bandiana. Specific details on the irrigation practices across the base were not provided, however during the inspections irrigation infrastructure was observed within gardens, across sporting ovals and across the golf course. An inspection of the Golf Course identified numerous mains water supply points across the area, which were reported as the irrigation supply points. The stock watering points are located within the leased sheep grazing areas (Figure 3). In addition to the reticulation-fed stock water points, a dam located within the grazing area on South Bandiana and fed by surface water run-off from Bears Hill is also used for watering the sheep on-base. It was reported, and observed during the investigation that sheep do not have access to the unnamed creek on North Bandiana, which is adjacent to the grazing area (Figure 3).

Prior to 2010, the Current Fire Training Area recycled wastewater used during training through the Current Fire Training Area sedimentation pond, however, this practice has now ceased (Section 9.1.6)

A review of information from North East Water identifies the property supply point as being two circular tanks positioned on the south-western flank of Huon Hill (North East Water, 2012).

WUS Results

Of the 2,161 WUS distributed, as of the 20 January 2018, 212 responses have been received. The following provides a statistical synopsis of the results obtained from these responses:

- 186 responses relate to residential properties (including two aged care / residential care properties); one relates to a school / childcare centre; 15 commercial, 11 industrial and three agricultural properties.
- Seventy-five percent of respondents stated living or occupying the property for in excess of ten years.
- 208 properties have water supplied to them via mains water—four do not. Of these four properties, three rely exclusively on rainwater and one relies on a combination of rain and bore water for domestic use.
- Twenty-four properties use rainwater, either to supplement mains water (20 properties), or rely on rainwater (four properties) in the absence of a mains water supply.
- The response from 42 properties (primarily those which use rainwater) stated having water tanks, although none were reported to have historically or currently contain bore water and none were reported to have been washed with bore water.
- 14 properties have surface water use on them; four with dams, three with wetlands, three with a creek; five with surface drains, two with one or more ponds, one with a river and one with a rainwater catchment.
- No properties use surface water for domestic use (drinking or other household use) although two stated swimming in surface water occasionally.
- Four properties use surface water (with differing seasonal frequencies) for watering fruit / vegetable gardens, watering the grounds, watering livestock, watering poultry and, occasionally for fire-fighting.
Four properties have bores:

- One property has multiple monitoring bores, the water from which is never used.
- One property uses water extracted from the bore to water the grounds of a commercial property for aesthetic purposes.
- One property uses water extracted from the bore for watering a fruit/vegetable garden, the grounds and, occasionally, livestock which are raised solely for household consumption.

The fourth property, on the periphery of the investigation area, uses water extracted from a shallow bore for domestic use (including drinking), watering a fruit/vegetable garden used solely for household purposes, and occasionally watering livestock and poultry, the use of which is mixed household and commercial. This property is not connected to mains water.

### 7.3 Identified Potential Receptors

Based on the current use of the BMA, most of the property would be considered to have a commercial/industrial land use, however selected areas of the BMA include more sensitive uses such as the primary school, the Bandiana Neighbourhood House, the residential facilities and select areas used for sheep grazing. The remaining areas of the BMA would be considered recreation/open space environments, albeit several of the BMA activities do not fall explicitly within the NEPM described land use categories (Section 5.2).

The broader area surrounding the BMA includes a wide range of land and water uses and associated potential receptors. A “receptor” to contamination could be either humans or ecology that could be exposed to PFAS if the linkages are complete between sources, pathways and receptors. Some potential receptors may be more sensitive to exposure to site-derived PFAS (than on-base receptors), and/or exposed in ways different to those of the on-base receptors (Plate 8).

![Plate 8: Conceptual Receptor Map](image-url)
In accordance with the Vic Land SEPP (2002), the Vic Groundwater SEPP (1997), and the Vic Surface Water SEPP (2003), the beneficial uses which have been considered as applicable to the BMA and the surrounding areas are discussed below and summarised in Table 12. This consideration applies to either Segment A or Segment B beneficial uses as outlined in the VIC Groundwater SEPP (1997). These SEPPs are further discussed in Appendix B.

In summary, based on these SEPPs, the following are considered as the beneficial uses of the land, surface water and groundwater that are protected and require assessment:

- **Maintenance of ecosystems (land, groundwater and surface water): On-base and off-base**
  
  Portions of the BMA, and the surrounding areas include natural, modified and highly modified environments where ecological receptors are likely to be present. Aquatic and terrestrial ecosystems, both on- and off-base are therefore potential receptors. These include on-base ecological receptors such as the significant kangaroo populations and off-base ecological receptors, such as those within the Kiewa and Murray Rivers which have valued flora and fauna, such as the Murray Cod.

- **Human health, buildings and structures and aesthetics (land): On-base and off-base**
  
  The BMA is an active facility with a wide range of uses, including several sensitive uses, such as the primary school, the Bandiana Neighbourhood House, and the residential facilities (Figures 2 and 3). Therefore, the on-base adult workers (including maintenance workers, office workers and army personnel), and adult and child residents or site users are also potential receptors. Similarly, the surrounding populations are also potential receptors, particularly with the re-development of the surrounding land (to residential use) and the encroachment of several new residential developments towards the BMA.

  In addition to the protection of human health, under the VIC Land SEPP (2002), contamination must not cause the land to be corrosive or to adversely affect the integrity of structures or building materials, and must not be offensive to the senses of human beings.

- **Food production (land), irrigation, stock watering, agriculture and gardens (groundwater and surface water): On-base and off-base**
  
  These beneficial uses exist on and around BMA. On-base, portions of South Bandiana along the base of Bears Hill and North Bandiana to the south-east of the unnamed creek are used for sheep grazing.

  Off-base and surrounding properties were observed to be used for cattle grazing and also sheep grazing may occur but was not observed off the base. Dairy production was also noted on the eastern side of the Kiewa River.

  Livestock, specifically beef cattle, whether produced for market or for home consumption, were observed to consume water sourced from surface water, particularly oxbow lakes.

  The Investigation understands from information provided by Goulburn-Murray Water there are no licenced off-takers in the Kiewa River (including the unnamed creek) or the Jack in the Box Creek within the Investigation Area though there are all small number of licenced extractors in the Wodonga Creek. These extractors in the Wodonga Creek include North East Waters’ offtake for the municipal town supply. Except for the North East Water extraction, details on the extractors within Wodonga Creek may include irrigation, stock watering, agriculture and gardens. Additionally, there is the potential for unlicenced extraction to be occurring.

  There are eight bores licenced for domestic and stock use, and three for irrigation purposes within the investigation area (Figure 1). Appendix J provides a detailed review of registered bore licences.
Observations during site investigation works identified two yabbie traps, one within Jack in the Box Creek to the north-west of the South Bandiana boundary fence and one along the unnamed creek as it exits North Bandiana underneath Whytes Road. Wild deer were also spotted on Bears Hill and along the Kiewa River floodplain. It was reported by local residents that deer are hunted locally, and duck hunting is also practiced within the region. Well established fruit trees, and vegetable gardens were also observed in the general surrounding area during the reconnaissance.

It is noted that the environmental data collected including soil sediment, surface water and groundwater cannot alone inform the risks of the consumption of aquatic species (e.g. fish, yabbies), eggs or meat, or for rural settings. The environmental data may be used to inform risk associated with the consumption of home grown produce in residential land use settings. Further discussion on the extent to which environmental data may inform the risks of food production / consumption are included within Appendix K which discusses the adopted screening guidance values.

- **Potable water supply (surface water and groundwater): Off-base**

  The North East Water extraction point, located on Wodonga Creek and is up-gradient of the primary confluence with Jack in the Box Creek. Based on information provided by North East Water, it is also understood that Wodonga Creek is influenced by both the Kiewa River and the upper Murray River.

  Based on the WUS results, the majority of respondents were connected to mains water and use mains water as the primary potable supply. Of the responses, four properties were not connected to mains water, and of these, three used harvested rainwater as the potable supply. The remaining property used a combination of harvested rainwater and extracted groundwater as the potable supply.

  Eight registered domestic stock bores were identified within the investigation area, and based on the classification of the groundwater (Segment A) the use of groundwater for domestic supply is a protected beneficial use.

- **Industrial water use (groundwater): Off-base**

  Groundwater is not extracted on the base (Section 7.1), therefore this beneficial use is not currently realised on the base.

  There are numerous industrial properties to the north-west of the BMA (within the Jack in the Box Creek catchment), where groundwater extracted for industrial use, with seven bores licenced for unknown or “non-groundwater” use within the investigation area. No industrial water use was identified through the WUS, however one commercial property with a registered extraction bore, used groundwater to water the grounds for aesthetic purposes.

- **Primary contact recreation (groundwater and surface water): Off-base**

  Groundwater is not extracted on the base, and on-base watercourses are not used for primary contact recreation (e.g. swimming). However, groundwater and surface water from BMA discharges to either the Kiewa River (to the east) or via Jack in the Box Creek to Wodonga Creek (an anabranch of the Murray River, to the north-west) where a range of primary and secondary contact (e.g. boating, kayaking, swimming) recreational activities occur. Furthermore, while the WUS responses did not indicate surface water extraction was occurring within the investigation area, extracted surface water is used as a supplementary supply for swimming pools or other domestic purposes. Furthermore, eight bores are licenced for domestic or stock use within the investigation area (Appendix F). Except for one property, the WUS responses did not indicate the extraction of groundwater for domestic purposes.
### Table 12: Summary of Protected Beneficial Uses and Potential Receptors

<table>
<thead>
<tr>
<th>Beneficial Use</th>
<th>SEPP</th>
<th>On / Off-base</th>
<th>Catchment</th>
<th>Potential Receptor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance of ecosystems</td>
<td>Land, Surface Water, Groundwater</td>
<td>On-base, Off-base</td>
<td>Jack in the Box Creek¹, Kiewa River²</td>
<td>Terrestrial ecosystems, Aquatic ecosystems</td>
</tr>
<tr>
<td>Human Health</td>
<td>Land</td>
<td>On-base, Off-base</td>
<td>Jack in the Box Creek¹, Kiewa River²</td>
<td>On-base residents &amp; sensitive receptors, On-base workers, On-base army personnel, Off-base residents &amp; sensitive receptors, Off-base recreational users, Off-base commercial / industrial workers</td>
</tr>
<tr>
<td>Food Production, Irrigation, Stock, Agriculture and Gardens</td>
<td>Land, Surface Water, Groundwater</td>
<td>On-base, Off-base</td>
<td>Jack in the Box Creek¹, Kiewa River²</td>
<td>On-base residents &amp; sensitive receptors, On-base workers, Off-base residents &amp; sensitive receptors, Off-base recreational users</td>
</tr>
<tr>
<td>Potable Water Supply</td>
<td>Surface Water, Groundwater</td>
<td>Off-base</td>
<td>Jack in the Box Creek¹, Kiewa River²</td>
<td>On-base residents &amp; sensitive receptors, Off-base residents &amp; sensitive receptors</td>
</tr>
<tr>
<td>Industrial water use</td>
<td>Groundwater</td>
<td>Off-base</td>
<td>Jack in the Box Creek¹</td>
<td>Off-base commercial / industrial users</td>
</tr>
<tr>
<td>Primary contact recreation</td>
<td>Surface Water, Groundwater</td>
<td>Off-base</td>
<td>Jack in the Box Creek¹, Kiewa River²</td>
<td>Recreational users of creeks, rivers &amp; oxbows</td>
</tr>
</tbody>
</table>

**Notes:**
1. Jack in the Box Creek Catchment drains to and includes Wodonga Creek.
2. Kiewa River Catchment includes the Kiewa River,Unnamed Creek and middle Creek and Drains to the Murray River.
8.0 ADOPTED SCREENING GUIDANCE VALUES

Within Australia, a tiered approach is used for the assessment of contaminated sites. The initial stage, Tier 1 screening level assessment, involves comparing the concentration of a contaminant against a guidance value.

Concentrations of PFAS reported in soil and water samples were compared against an adopted set of screening guidance values as part of a Tier 1 screening level assessment (Appendix K). Based on the results of this comparison, areas may be not present a risk, or may require further assessment through the HHERA, and/or management through the implementation of mitigation measures. The HHERA is used to confirm if an unacceptable risk exists, and if so, how significant that may be. Once the risks are further understood and technically evaluated, where required plans will be put in place to mitigate risks through the PMAP.

Guidance values from PFAS National Environmental Management Plan (NEMP) (Heads of Environmental Protection Authorities Australia and New Zealand (HEPA), January 2018) have been adopted for the Tier 1 screening level assessment of the DSI. The guidance values presented in the NEMP (HEPA, 2018) have been derived from existing nationally agreed values or international guidance values where local values are unavailable. The adopted guidance values are detailed in Table 13 for human health and Table 15 for ecological receptors.

Due to the lack of scientific characterisation regarding toxicity and mode of action for many of the PFAS, it is not proposed to subject PFAS compounds other than PFOS, PFOA, and PFHxS to the screening assessment. But a qualitative interpretation of detections in the context of publicly available scientific knowledge has been completed as part of the DSI and will also be considered in subsequent risk assessment stages.

Sediment screening guidance values have not yet been provided for either human health or ecological receptors as there are currently no nationally accepted human health or ecological guidance values for PFAS in sediment. However, for the purposes of the DSI and in consideration of scenarios where people have the potential to come into contact with sediments (i.e. maintenance workers or river swimming), sediment samples were screened against soil guidance values for the protection of human health. This approach is considered conservative, as the soil screening levels are derived using exposure routes (such as incidental injection and inhalation of dust) which may not be relevant, particularly for sediments which are permanently saturated. The nature of the sediments (i.e. dry or saturated) and limitations of using soil screening guidance values for sediments have been considered where exceedances have occurred.

For ecological purposes, sediment samples collected from drainage lines frequently observed to be dry during the investigation were screened against interim soil ecological guidance values, and samples from areas frequently observed to be wet or inundated were considered against the LOR for PFOS, and PFOA.

Soil screening guidance values for PFAS for the protection of human health in rural land use settings where poultry and livestock are raised and consumed have not been developed in Australia. The guidance values from NSW Office of Environment and Heritage (OEH), (2017) specify that standard (low density) residential guidance values should not be applied to rural settings. Therefore, for the purposes of the DSI, soil samples collected from rural settings will be screened using the laboratory LOR.
Table 13: Adopted Soil, Groundwater and Surface Water Screening Guidance Values for Human Health

<table>
<thead>
<tr>
<th>Exposure Scenario</th>
<th>PFOS + PFHxS</th>
<th>PFOA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Soil</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential with garden / accessible soil (mg/kg) (low density residential)</td>
<td>0.009 a</td>
<td>0.1 a</td>
</tr>
<tr>
<td>Residential with minimal opportunities for soil access (high density residential) (mg/kg)</td>
<td>2 a</td>
<td>20 a</td>
</tr>
<tr>
<td>Commercial / industrial premises (mg/kg)</td>
<td>20 a</td>
<td>50 a</td>
</tr>
<tr>
<td>Public open space use (mg/kg)</td>
<td>1 a</td>
<td>10 a</td>
</tr>
<tr>
<td><strong>Surface water and Groundwater</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drinking water (µg/L)</td>
<td>0.07 b</td>
<td>0.56 b</td>
</tr>
<tr>
<td>Recreational water (µg/L)</td>
<td>0.7 b</td>
<td>5.6 b</td>
</tr>
</tbody>
</table>

Notes:
- a Guidance values from NEMP 2018 (based on FSANZ TDI)
- b Guidance values from NEMP 2018 (adopted from Australian Government Department of Health 2017)
- LOR Limit of reporting
- µg/L microgram per litre
- mg/kg milligram per kilogram
- PFAS Per- and Poly- Fluoroalkyl Substances
- PFOS Perfluorooctanesulfonic acid
- PFOA Perfluorooctanoic acid
- PFHxS Perfluorohexane sulfonic acid

The NEMP includes interim direct and indirect exposure soil guidance values for ecological receptors. The NEMP soil guidance values for screening indirect exposure pathways have been adopted from the Canadian Federal Environmental Quality Guidelines (FEQG) (Environment and Climate Change Canada, February 2017). The adopted soil guidance values for indirect exposure in the NEMP are for residential and commercial / industrial land use, and as stated in the NEMP they are intended to be protective of the various pathways in which organisms can be exposed due to bioaccumulation and / or off-site transport. The 2017 Canadian FEQG for residential land uses also includes parkland. Therefore, it is considered that the residential guidance value for screening indirect exposure pathways are also applicable to open space areas.

The NEMP also provides soil guidance values for screening direct exposure pathways for ecological receptors in public open space land use settings. As stated in the NEMP, in the absence of acceptable published guidance values, the direct exposure guidance values are based on the human health guidance values for soil.

It is important to note that both the direct and indirect exposure soil guidance values within the NEMP are interim, with further research stated in the NEMP to be undertaken by Australian Government and industry organisations. It is anticipated that the NEMP will be updated in mid to late 2018. Further discussion on the adopted ecological soil guidance values is included in Appendix K.
The NEMP has adopted the Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia (ARMCANZ) (2000) trigger values or species protection levels for toxicants (as endorsed by the Vic Surface Water SEPP [2003], and the Vic Groundwater SEPP [1997]) which provide guidance for assessment of aquatic ecosystems. Percent species protection levels of 80%, 90%, 95% and 99% apply to ecosystems of varying modification or disturbance with 80% applying to highly disturbed systems and 99% applying to largely unmodified systems. A system defined as slightly to moderately disturbed may be assessed using the 95% species protection level. However, for bioaccumulative / biomagnifying toxicants (such as PFAS) an increased level of species protection is adopted i.e. for an aquatic ecosystem described as slightly to moderately disturbed the 99% species protection level is adopted.

The waterbodies on- and off-base meet varied descriptions of ecosystem disturbance and modification ranging from highly modified (for example the channelised portions of Jack in the Box Creek, and the unnamed creek) to slightly to moderately disturbed (for example Wodonga Creek, and the Kiewa River). In accordance with the Vic Surface Waters SEPP (2003), the following has been considered to determine the species protection level for on- and off-base surface water:

- In accordance with the Vic Surface Waters SEPP (2003), the BMA falls under the segment of the Murray and Western Plains, and has been assigned a classification of “slightly to moderately modified” for all waterways.
- The Vic Surface Waters SEPP (2003), under clauses 46 and 51, does not require the protection of beneficial uses in artificial stormwater drains and artificial wetlands. The SEPP notes that these environments need to be managed for purposes for which they were constructed and must be managed to not cause harm to human health or the environment.
- Based on the above, the species protection levels adopted for various surface water features are identified in Table 14.

Table 14: Surface water adopted species protection levels

<table>
<thead>
<tr>
<th>Surface Water Feature</th>
<th>Description</th>
<th>Species Protection Level</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>On-Base</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drainage channel</td>
<td>Shallow, intermittently inundated, man-made drain designed to manage surface water flows during rainfall.</td>
<td>None</td>
</tr>
<tr>
<td>including unnamed creek</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lined pond</td>
<td>Man-made pond lined with either concrete or HDPE, used for current or former training purposes.</td>
<td>None</td>
</tr>
<tr>
<td>Stormwater pond</td>
<td>Unlined man-made pond designed to improve water quality and permanently inundated. Established vegetation present within and/or around pond. Highly disturbed¹ but considered to support freshwater ecosystems.</td>
<td>95%</td>
</tr>
<tr>
<td>(wetland or settling pond)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unlined pond or dam</td>
<td>Unlined man-made pond or dam permanently inundated. Established vegetation present within and/or around pond. Highly disturbed¹ but considered to support freshwater ecosystems.</td>
<td>95%</td>
</tr>
</tbody>
</table>
### Surface Water Feature

<table>
<thead>
<tr>
<th>Surface Water Feature</th>
<th>Description</th>
<th>Species Protection Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water feature at base boundary (e.g. drainage channel, pond etc.)</td>
<td>To comply the Vic Surface Waters SEPP (2003), and to account for bioaccumulation, the 99% species level of protection has been adopted for the Tier 1 screening assessment of surface water samples collected from water bodies near the base boundaries which are about to enter off-base environments.</td>
<td>99%</td>
</tr>
</tbody>
</table>

### Off-Base

<table>
<thead>
<tr>
<th>Off-Base</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>All water bodies</td>
<td>To comply the Vic Surface Waters SEPP (2003), and to account for bioaccumulation, the 99% species level of protection has been adopted for the Tier 1 screening assessment of all off-base surface waters.</td>
<td>99%</td>
</tr>
</tbody>
</table>

#### Notes:

1. Highly disturbed systems are generally screened against the 90% species protection level. However, in accordance with ANZECC 2000 to account for the bioaccumulative / biomagnifying nature of PFAS an increased level of species protection is adopted.

In accordance with the Vic Groundwater SEPP (1997), the Maintenance of Ecosystems is a protected beneficial use, where “groundwater shall not cause receiving waters to be affected to the extent that the level of any water quality indicator is greater than the level of that indicator specified in the relevant State environmental protection policy for surface waters.” The NEMP notes that it should be assumed that groundwater is connected to surface waters surrounding the site. The 99% species level of protection has been adopted for the Tier 1 screening assessment of groundwater within the wells immediately up-gradient of receiving surface water bodies. Groundwater wells considered to be immediately up-gradient of receiving surface water bodies are identified in Section 6.6.4.

For completeness, the trigger values for all levels of species protection that apply to PFAS are presented in Table 15.

#### Table 15: Adopted Soil, Groundwater and Surface Water Screening Guidance Values for Ecological Receptors

<table>
<thead>
<tr>
<th>Exposure Scenario</th>
<th>PFOS</th>
<th>PFOA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Soil – Indirect Exposure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parkland / low density residential (mg/kg)</td>
<td>0.01 a, b</td>
<td>-</td>
</tr>
<tr>
<td>Commercial / industrial (mg/kg)</td>
<td>0.14 b, c</td>
<td>-</td>
</tr>
<tr>
<td><strong>Soil – Direct Exposure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public open space (mg/kg)</td>
<td>1 b, d</td>
<td>10 d</td>
</tr>
<tr>
<td><strong>Freshwater</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High conservation / ecological value systems (99% species protection) (µg/L)</td>
<td>0.00023 b, c</td>
<td>19 c</td>
</tr>
</tbody>
</table>
### 9.0 RESULTS

The PFAS source assessment, summary of the sampling and analytical plans implemented, and the results of the intrusive investigation including visual observations and field measurements (Tables A to E) and analytical results (Tables F to Q) are provided in the sections below. Summaries for the sampling plans implemented at each area include an indication of any deviations from the approved SAQP, either as a scope inclusion or scope exclusion item. Deviations from the SAQP, in particular scope exclusions, are further discussed in Section 10.3.1.

Figure 10 provides an overview of the identified PFAS source areas across the BMA. Figures 11 to 13 present the on-base sample locations for soil (Figure 11 series), groundwater (Figure 12 series) and sediment/surface water (Figure 13 series).

Off-base sample locations are similarly illustrated on Figure 14 series (soil), Figure 15 series (groundwater) and Figure 16 (sediment/surface water). It is noted, due to privacy agreements not all off-base sample locations are depicted on figures, these included samples from: MW347, SS326, SW/SD406, SW/SD408, SW/SD410, SW/SD413, SW/SD399, SW/SD442, SW/SD444, SW/SD464 and all point of use samples.

Broadly the results are presented in the following order:

- **On-base Source Areas (Section 9.1):** this includes a description of operations and features related to the use of AFFF within the identified source areas, and the results for sampling locations immediately within each source area. The source areas are generally described moving from west to east across the BMA.

- **On-base Sensitive Receptors (Section 9.2):** this includes the Bandiana Neighbourhood House and Bandiana Primary School.

- **On-base General Coverage (Section 9.3):** this includes a summary of potential diffuse sources and the results for sampling locations which aimed to address diffuse sources and provide general coverage across BMA, including boundary and background conditions.

- **Off-base Catchment Areas (Section 9.4):** this includes a summary of potential off-base PFAS sources, and results for the sampling locations primarily along off-base surface water systems including the Kiewa River, Murray River, Jack in the Box Creek and Wodonga Creek.

### Exposure Scenario

<table>
<thead>
<tr>
<th>Exposure Scenario</th>
<th>PFOS</th>
<th>PFOA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slightly to moderately disturbed ecosystems (95% species protection) (µg/L)</td>
<td>0.13</td>
<td>220 c</td>
</tr>
<tr>
<td>Highly disturbed ecosystems (90% species protection) (µg/L)</td>
<td>2 b, c</td>
<td>632 c</td>
</tr>
</tbody>
</table>

Notes:
- a: Investigation levels from NEMP 2018 (adopted from ECCC 2017)
- b: Investigation levels or guidance value for PFOS only (PFHxS not included in derivation).
- c: Investigation levels from NEMP 2018 (based on DoEE 2016)
- d: Investigation levels from NEMP 2018 (based on the Human Health Soil Criteria for public open space which is based on FSANZ TDI)

**µg/L** microgram per litre

**mg/kg** milligram per kilogram

**PFAS** Per- and Poly-Fluoroalkyl Substances

**PFOS** Perfluorooctanesulfonic acid

**PFOA** Perfluorooctanoic acid
Off-base Point of Use (Section 9.5): this includes results for sampling from selected private properties where WUS were completed.

In addition to the sections below, the following supporting documentation is appended to this DSI report:

- The methodologies used to undertake the source assessment and intrusive investigations are provided in Appendix C.
- Additional information relating to the Sampling and Analysis Quality Plans (SAQPs) is provided in Appendix D.
- Borehole logs for soil bores, test pits and groundwater monitoring wells are included in Appendix F.
- Groundwater well development records and groundwater sampling records are included in Appendix H and Appendix I respectively.
- The quality assurance / quality control (QA / QC) plan and review is included in Appendix L and data validation sheets are included in Appendix M.
- Laboratory analytical certificates are included in Appendix N.

9.1 On-base Source Areas

9.1.1 Source Area 1 – Petroleum Platoon – Former Fire Training Ground (RMV0112) [South Bandiana]

The Former Fire Training Ground, utilised by the Petroleum Platoon prior to 1994, is located in the western portion of South Bandiana in a large area of vacant land known as the Close Training Area (Figure 2). The Petroleum Platoon historically used the area for fuel handling training and fire training exercises prior to the construction of the current facilities utilised at South Bandiana (Sections 9.1.5 and 9.1.6). This area is identified as current Defence Contaminated Site Register (CSR) entry reference RMV0112.

During the site inspection, the area was observed to comprise an earthen bund and two open metal sheds approximately 150 m east and north-east of the earthen bund. It is understood that two large concrete bunded areas (now removed) were historically associated with the two metal sheds and used to house mobile petroleum above ground storage tanks (ASTs, now removed) for fuel handling training (Golder, 2012). Based on interviews undertaken during the site inspection it is understood that the earthen bund area was specifically used for fire training activities, prior to 1994. GHD (2003) reported that training activities included filling the earthen bund with water, transferring fuel into the bund and setting it alight, and utilising fire-fighting foam to extinguish the fire.
A valve was noted on the northern side of the earthen bund during the site inspection, presumably for draining the pit following the completion of fire training activities. A number of blackened circles, approximately 1 m in diameter, were also noted on the ground surface in the vicinity of the earthen bund. It is presumed that these blackened circles are relics of the small-scale fire training activities which were reportedly undertaken prior to combating the larger fire in the earthen bund. Defence personnel also reported during the site inspection that small scale fire training may have been undertaken in the vicinity of the metal sheds.

Limited information was available from the Defence personnel interviewed regarding the frequency of training activities or the AFFF products used in this area. However, on the basis of the information provided during the Golder 2017 site interviews, it is considered likely that the training activities undertaken in this area were similar in frequency to those currently undertaken by the Petroleum Platoon at the Current Fire Training Area (Section 9.1.6). It is also considered likely that the main AFFF product used was 3M Lightwater, based on the facility being used prior to 1994, however, this could not be confirmed from the available Defence personnel interviewed.

A number of historical soil investigations have been undertaken in the vicinity of the two metal sheds and the earthen bund (Hyder 1998, GHD 2003 and Golder 2012) at CSR site RMV0112. PFAS analysis in ten surface soil samples within and surrounding the earthen bund was undertaken by Golder (2012). Concentrations of PFOS were reported in each of the ten soil samples with concentrations ranging from 0.0315 to 1.04 mg/kg. Concentrations of PFOA were reported in nine samples ranging from 0.0006 to 0.0064 mg/kg. There have been no known prior investigations of groundwater in the Close Training Area.

Golder (2012) reported that the northern portion of the Close Training Area was subject to flooding and as such has never been developed. Ponded water was observed in the earthen bund during the inspection in 2017 and in the drainage channels running through the area. Surface water from the earthen bund and the area immediately surrounding drains to the north north-west, and discharges from the Close Training Area through bushland within Jack Perry Reserve. Surface water runoff in the vicinity of the two metal sheds drains directly to the north via drainage channels and swales before joining Jack in the Box Creek.

**Sampling Plan**

The sample locations are presented on Figures 11A, 12A and 13A. For further details Appendix D presents the sampling completed within the area of interest.

**Soil Results**

The source area is within an open space land use setting (Figure 3). The surface sample at 0445S_MW307, located north of the earthen bund (i.e. along the down-gradient flow path), reported concentrations of PFOS+PFHxS of 1.04 mg/kg which exceeded the open space human health guidance value of 1 mg/kg.

Exceedances of the interim direct open space (1 mg/kg) and indirect residential / parkland (0.01 mg/kg) soil ecological guidance values for PFOS were noted.
Groundwater Results
The PFAS exceedances of the human health guidance values included:

- The groundwater sample collected from 0445S_MW307 located directly down-gradient (north) of the earthen bund reported concentrations of 0.43 µg/L of PFOS+PFHxS which exceeded drinking water guidance values (0.07 µg/L).
- The groundwater sample collected from 0445S_MW311 located directly down-gradient (north) of one of the open sheds reported concentrations of 0.10 µg/L of PFOS+PFHxS which exceeded drinking water guidance values (0.07 µg/L).

Surface Water and Sediment Results
Surface water samples were not able to be collected from within the source area, with the exception of 0445S_SW316, as the drainage channels were observed to be dry. The surface water sample collected at 0445S_SW316 reported 1.11 µg/L of PFOS+PFHxS which exceeded the human health recreational water (0.7 µg/L) and the drinking water (0.07 µg/L) guidance values.

There were no reported exceedances of the open space human health soil guidance values for PFAS in sediment. The drainage channels within the source area were frequently observed to be dry during the investigation, therefore, the reported sediment sample concentrations have been compared against the open space soil guidance values for ecological purposes.

Exceedances of the interim direct open space (1 mg/kg) and indirect residential / parkland (0.01 mg/kg) soil ecological guidance values for PFOS were noted in sediment samples.

9.1.2 Source Area 2 – Base Fire Services – Former Fire Training Ground [South Bandiana]

The Base Fire Services historically operated a fire training ground, in the south-western portion of the current Close Training Area (Figure 10, Source Area 2). Defence personnel interviewed indicated that this facility was operated in an approximate timeframe of 1980s to 1990s. The facility included a concrete run, pressure vessel, pipe work, sump and “header unit”. It was reported by the Defence personnel interviewed that the facility operated by filling the pressure vessel with fuels (typically petrol), pressurising the vessel using a fire pump, and then igniting the pressurised fuel released through the header unit. The intensity of the fire could be controlled by manipulating the pressure being applied.
Interview information with Defence personnel indicated that training activities were typically completed on a monthly basis, however, varied subject to the requirements of the military unit at the time. It was reported that an allowance of approximately one drum of foam was allocated per person per month for training purposes, and the posted strength of the unit was historically up to 28 personnel (amounting to approximately 560 litres (L) per annum of AFFF based on 28 x 20 L drums per month). On occasion the monthly training stock allowance was dedicated for more intensive training activities to be completed, as required. This area likely ceased being used in approximately 1993, with the installation of the Current Fire Training Area (Section 9.1.6), and when the on-base fire services moved to the Current Fire Station located on East Bandiana (Section 9.1.6). The main AFFF product used was reported by Defence personnel as 3M AFFF, which aligns with the time the facility was operated, however, some training may have included the use of bush fire-fighting foam (BFFF).

During the site inspection, the area was generally open ground with short grass and scattered trees. The pressure vessel was observed and included a corrugated iron heat shield. The header unit was observed as steel piping exiting the ground approximately 25 m north-west of the pressure vessel and standing approximately 2 m tall, and a concrete sump was observed at the north-western end of the concrete run and was covered with corrugated iron. Within the surrounding area, a small shallow earth dam was observed approximately 10 m south-west of the concrete run, and blackened earth was evident on the southern embankment of the dam. A small rectangular concrete pond with associated pipe work was observed approximately 45 m south-west of the concrete run. While not reported during interviews as being directly associated with the training ground, given the proximity to the facility, there is potential the earth dam was used for training. The concrete pond may also have been associated with the facility as a potential water supply point for the fire-fighting activities. Stockpiles of soil and concrete rubble overgrown with vegetation were also present in the area approximately 20 to 25 m west and north-west of the facility.

This former fire training ground (Source Area 2) had not been previously identified in prior assessments and therefore, had not been previously investigated for PFAS contamination.

A formal drainage network was not apparent in the area, and the topography sloped gently to the north-west. Drainage from the area flows to the north-west, entering the drainage lines running to the north along the western property boundary before ultimately joining Jack in the Box Creek.

**Sampling Plan**

The sample locations are presented on Figures 11B, 12B and 13B. For further details Appendix D presents the sampling completed within the area of interest.

**Soil Results**

The source area is within an open space land use setting (Figure 3). The surface sample at 0445S_MW317 reported concentrations of PFOS+PFHxS of 1.23 mg/kg which exceeded the open space human health soil guidance value of 1 mg/kg. Sample 0445S_MW317, is located north of the small shallow earth dam (i.e. along
the down-gradient flow path). No samples exceeded the commercial/industrial human health soil guidance values.

Exceedances of the interim direct open space (1 mg/kg) and indirect residential/parkland (0.01 mg/kg) soil ecological guidance values, and the interim indirect commercial/industrial (0.14 mg/kg) soil ecological guidance values for PFOS were noted.

**Groundwater Results**

There were no reported PFAS exceedances of the human health guidance values.

**Surface Water and Sediment Results**

Surface water samples were not able to be collected from within the source area, with the exception of 0445S_SW305, as the drainage channels were observed to be dry. The PFAS concentrations in the surface water sample collected at 0445S_SW305 were below the adopted human health guidance values.

No sediment samples exceeded the commercial/industrial human health soil guidance values. There were three reported exceedances of the open space human health soil guidance values for PFAS in sediment. These include exceedances of PFOS+PFHxS (1 mg/kg) at the following locations:

- The sediment samples collected from 0445S_SD304 (13.3 mg/kg) within the small shallow earth dam and 0445S_SD303 (2.38 mg/kg) located along the down-gradient flow path to the north of the small shallow earth dam.

- The sediment sample collected from 0445S_SD302 (5.57 mg/kg) located along the down-gradient flow path of the concrete run and small shallow earth dam.

The drainage channels within the source area were frequently observed to be dry during the investigation, therefore, the reported sediment sample concentrations have been compared against the open space soil guidance values for ecological purposes.

Exceedances of the interim direct open space (1 mg/kg) and indirect residential/parkland (0.01 mg/kg) soil ecological guidance values for PFOS were noted in sediment samples.
9.1.3 Source Area 3 – Potential Disposal Burial Ground [South Bandiana]

A potential disposal ground was identified during the site inspection in the southern portion of the Close Training Area, at the base of Bear’s Hill (Figure 10, Source Area 3). The site inspection identified an uneven ground surface with a number of partially buried metal objects and a number of rusted, discarded 200 L drums. Interviews with site personnel indicated that burnt material was encountered during road upgrade works in 2012 which included construction of a ford (crossing), however, there was no other information available regarding the type of waste disposed in this area. It is noted that the BFS Former Training Ground was located approximately 200 m to the north-west (Section 9.1.2) and as such it is feasible that AFFF related wastes from Source Area 2 may have been disposed at Source Area 3.

Surface water runoff from this area is considered to drain to a dam located approximately 200 m to the north, from where it is likely to drain to the north into a drainage channel to the east of the metal sheds formerly used by the Petroleum Platoon for fuel handling training (Section 9.1.1) and into Jack in the Box Creek.

Sampling Plan

The sample locations are presented on Figure 11C. For further details Appendix D presents the sampling completed within the area of interest.

Soil Results

The source area is within an open space land use setting (Figure 3). There were no reported PFAS exceedances of the open space human health soil guidance values.

There were no reported PFAS exceedances of the interim direct open space (1 mg/kg) or indirect residential/parkland (0.01 mg/kg) ecological soil guidance values.

9.1.4 Source Area 4 – Former 25m Firing Range (Within RMV0119) [South Bandiana]

A historic 25 m Firing Range was identified via the interviews undertaken as an area where waste dumping had historically occurred. The range is located at the base of Bears Hill, to the south of the Close Training Area (Figure 10, Source Area 4), and was described in Maunsell / CH2M Hill (2006) as a 50 m by 30 m dome shaped area with a rock and concrete slurry-treated stop butt cut out of the side of the hill. It was reported that the range was used for the disposal of waste materials, and given the area is located approximately 250 m from the former BFS Former Training Ground there is potential that AFFF related wastes may have been disposed in this area.

The area was investigated in 1998 by Hyder, in 1999 by GHD and in 2006 by Maunsell / CH2M Hill (Golder, 2012). The previous investigations did not analyse PFAS compounds.
Surface water runoff from this area will drain through the potential Disposal Ground identified to the north, then to a dam located approximately 250 m to the north. Ultimately, the water will drain into Jack in the Box Creek.

**Sampling Plan**

The sample locations are presented on Figure 11C. For further details Appendix D presents the sampling completed within the area of interest.

**Soil Results**

Source Area 4 is within an open space land use setting (Figure 3). There were no reported PFAS exceedances of the open space human health soil guidance values.

There were no reported PFAS exceedances of the interim direct open space (1 mg/kg) or indirect residential / parkland (0.01 mg/kg) ecological soil guidance values.

9.1.5 **Source Area 5 – Petroleum Platoon – Fuel Handling Facility (RMV0007) [South Bandiana]**

The Petroleum Platoon Fuel Handling Facility (Defence CSR site reference RMV0007), which is operated by the ASO, is located in the central-northern portion of South Bandiana (Figure 10, Source Area 5). The facility provides an area for training in refuelling of vehicles and bulk fuel handling. The Fuel Handling Facility includes:

- Three large open training shelters (Asset 808, 809 and 826) accessed via a circular road with associated earthen bunds (Asset 810, 811 and 812) where vehicles can be refuelled using temporary bulk fuel storage bladders. Each training shelter has a concrete surface which drains to a triple interceptor trap located to the north of the central training shelter (Asset 809). The triple interceptor trap was replaced in early 2017. Golder (2012) reported that each of the earthen bunds had a large metal pipe through the bund, which lead to the concrete training shelter area. It is understood that these pipes were historically used for transferring fuel from the fuel storage bladders (located within the earthen bunded areas during training) into the sheltered area to dispensing tanks or vehicles. These pipes were reported by Defence to be no longer in use. Flexible hoses now run over top of the earthen bund for use during training.
- A pond (Asset 813) which sits on a high point within the central area of the Fuel Training Facility. The pond is reportedly filled with water using nearby fire hydrants.

- Two hardstand areas which are reportedly used for fuel transfers (Asset 951) and fuel tanker wash down (Asset 952). Golder (2012) reported that each area has its own stormwater system which include oil / water separators.

- A fenced storage compound (Buildings 748 and 849) which currently contains training foam. It was reported by Defence personnel interviewed that historical AFFF products (PFAS containing) were formerly stored within this compound.

- An electrical substation (Building 576) that services South Bandiana.

- A small petroleum laboratory (shipping container) designed to simulate a mobile laboratory for petrochemical testing, established for training purposes.

During the site inspection with available staff, it was reported that there had been no known major fuel releases during training exercises and that AFFF use within the training shelters was limited as the facility was not designed to contain AFFF waste. The facility’s triple interceptor trap does not process AFFF. Review of historical reports have, however, noted the following fuel related incidents:

- Golder (2012) reported that interviews with site personnel identified an incident involving a broken transfer pipe (metal pipes in between the earthen banded area and concrete shelter area) during training, which lead to potential soil hydrocarbon contamination likely at Tank Farm 2 in the early- to mid-2000s.

- Maunsell / CH2M HILL (2006) reported that a large spill of hydrocarbons had historically (~1994 / 1995) occurred along the western boundary of the Fuel Handling Facility. Golder (2012) reported that this incident resulted in Defence upgrading the banded areas and connection to the collection / separation system.

The site interviews conducted with ASO personnel during July 2017 identified that AFFF has historically been used in the Fuel Handling Facility for equipment testing and fire training activities, primarily in the open grassed area to the west of the fenced storage compound. A number of patches of bare earth were identified in this area during the site walkover. It was also reported that the small grassed area to the east of Building 298 (a training warehouse located to the south of the Fuel Handling Facility) was used to disassemble, empty and reload 9 kg fire extinguishers prior to 2010. The ground in this area was largely observed to be bare during the site walkover. The task of servicing fire extinguishers has been undertaken off-base by contractors since 2010. Limited information was available regarding the frequency of training activities or the AFFF products used.

Previous intrusive investigations at the Fuel Handling Facility have included soil and groundwater sampling for metals, total recoverable hydrocarbons (TRH), benzene, toluene, ethylene, xylene and naphthalene (BTEXN), polycyclic aromatic hydrocarbons (PAHs) and phenols. There has been no known analysis of PFAS in soil, sediment, surface or groundwater within the Fuel Handling Facility as part of prior investigations.

The three groundwater wells installed by Maunsell / CH2M HILL (2006) were gauged during the site inspection. The groundwater levels ranged between 165.74 m AHD and 166.56 m AHD (approximately 15 to 18 m bgl).

A review of site service diagrams and historical reports, and site observations and interviews were used to assess the complex drainage system within the Petroleum Platoon Fuel Handling Facility. It was established that surface water runoff and stormwater at the Fuel Handling Facility generally drains in two directions, either to the west towards Jack in the Box Creek or to the north towards the stormwater collection ponds (wetlands) at the entry to South Bandiana. Based on the information available, drainage within the area is summarised as follows:

- The concrete bunded area within each training shelter drains to the triple interceptor trap to the north of the central shelter (historically referred to as Tank Farm 2). Golder (2012) noted that water from the interceptor is discharged to stormwater drains and ultimately to the stormwater ponds (wetlands). However, it is noted that service diagrams identify both stormwater and sewer drains in the vicinity of the interceptor. Furthermore, the interceptor was replaced in early 2017, and as such the details provided in the Golder (2012) investigation are outdated, but reflect earlier understanding of historical discharge systems.

- The vast majority of the grassed area within the Fuel Handling Facility, approximately from the eastern edge of western training shelter (Structure 826) and associated bund (Structure 812) to the eastern boundary of the Fuel Handling Facility, drains via formed open spoon drains to the stormwater ponds.
(wetlands). This includes the area where equipment testing and fire training activities were undertaken. The grassed area from western edge of western training shelter drains towards Jack in the Box Creek.

- The concrete hardstand area within the storage compound drains to a pit in the north-western corner of the compound which is likely to drain to a sewer based on the service diagrams provided. However, a head wall and spoon drain was observed at the north-eastern edge of the compound which drains to the stormwater ponds (wetlands).

- The hardstand area used for fuel tanker wash down (Asset 952) drains to a triple interceptor trap (Structure 953) located at the south-western edge of the hardstand area. The interceptor discharges to an open stormwater drain to the west which flows in a north-westerly direction, underneath Lloyd Road and then joins an open stormwater drain which flows to the west, parallel to Lloyd Road, and eventually to Jack in the Box Creek. It is noted that during heavy rainfall events, the stormwater drain parallel to Lloyd Road could potentially overflow and water may also drain to the stormwater ponds (wetlands).

- The hardstand area used for fuel transfers (Asset 951) drains into a large three metre diameter sump via a triple interceptor adjacent to Building 597, which is then pumped through an oil / water separator before being discharged to an open stormwater channel to the north which drains to the stormwater ponds.

**Sampling Plan**

The sample locations are presented on Figure 11D, 12D and 13D. For further details Appendix D presents the sampling completed within the area of interest.

**Soil Results**

The Petroleum Platoon Fuel Handling area is representative of both open space and commercial / industrial land uses (Figure 3) as the area contains both hardstand and large grassed areas used for training purposes.

There were no PFAS exceedances of commercial / industrial human health soil guidance values.

PFAS exceedances of the open space health soil guidance values included:

- Surface soil location 0445S_SS311, located directly adjacent to Building 298, which reported a concentration of PFOS+PFHxS of 12.6 mg/kg which exceeded the human health open space soil guidance values (1 mg/kg).

Exceedances of the interim direct open space (1 mg/kg) and indirect residential / parkland (0.01 mg/kg) soil ecological guidance values, and the interim indirect commercial / industrial (0.14 mg/kg) soil ecological guidance values for PFOS were noted.

**Groundwater Results**

There were no reported PFAS exceedances of the human health guidance values.

**Surface Water and Sediment Results**

Surface water samples collected from within the source area reported the following notable concentrations with respect to human health guidance values:

- Surface water samples collected from the drainage channel running parallel to the northern boundary (i.e. along the down-gradient flow path) of the source area and from the large pond located within the facility reported concentrations of PFHxS+PFOS that exceeded the human health recreational water (0.7 µg/L) and the drinking water (0.07 µg/L) guidance values. These locations included 0445SS_SW340 (6.8 µg/L), 0445SS_SW342 (2.8 µg/L), 0445SS_SW338 (5.28 µg/L) and 0445SS_SW344 (2.87 µg/L).
Concentrations of PFHxS+PFOS in sample 0445S_SW333 (0.577 µg/L) collected from the junction of two drainage channels at the north-west corner of the source area exceeded the human health drinking water (0.07 µg/L) guidance values.

There were no reported exceedances of the open space and commercial / industrial human health soil guidance values for PFAS in sediment.

The drainage channels within the source area were frequently observed to be dry during the investigation, except for the drainage line running north-west to south-east along the northern perimeter of the source area. Given that water was frequently observed within this drainage line the samples collected from this drainage line, including SD333, SD337, SD340, SD341, SD342 and SD344, have been screened against the LOR for ecological purposes. The remaining sediment samples collected from areas frequently observed to be dry, including SD339, SD343 and SD345, have been compared against the open space and commercial / industrial ecological soil guidance values.

Sediment locations frequently observed to be dry reported exceedances of the interim indirect (0.01 mg/kg) residential / parkland soil ecological guidance values for PFOS. PFOS and PFOA were also detected above the LOR at locations with consistent water coverage.

9.1.6 Source Area 6 – Current Fire Training Area, Building 600 (RMV0005) [South Bandiana]

The Current Fire Training area, is operated by the ASO, and is located in the central-western portion of South Bandiana (Figure 10, Source Area 6). This area is identified as Defence CSR site reference RMV0005. Constructed in approximately 1993, the facility consists of a large shallow concrete bund, covered with a metal grill forming a platform on which the training activities take place. The training features include a mock fuel tanker and various trays, and two 200 L drums cut in half and mounted on stands, which are used for lighting small fires for fire extinguisher training. A brick wall bounds a portion of the southern and eastern sides of the training pad. While in operation, the concrete bund is designed to fill with water and cover the grill (to insulate the grill), with the trainees approaching the flame zone from the west. (i.e. spraying foam to the east). The larger fires are fuelled by eight large LPG cylinders, however smaller liquid fuel-based fires are also set in the trays and drums present in the facility.

The facility has undergone a series of upgrades following commissioning. EarthTech (2005) reported on an upgrade occurring approximately 12 months prior to their investigation, and it was reported by Defence personnel during the Golder inspection that additional minor upgrades occurred in approximately 2010. The 2004 upgrades included the installation of the concrete wall, and the first flush retention system and these works are depicted in the Operation Manual for the Aqueous Film Forming Foam (AFFF) Equipment Testing and Training Facility at the Albury Wodonga Military Area, South Bandiana Site, Indigo Way Services, 7 Sept 2004.
Currently, fresh water obtained from the hydrants is used for each training activity, with the water and foam released on the training platform draining to two large in-ground stormwater retention tanks, which are designed to capture the first flush of water from the training platform. Following the first flush, the remaining water is directed into the facility sediment pond by switching a series of valves. It was unclear whether the water in either the first flush tanks or the sediment pond is subsequently discharged to stormwater or to sewer. The 2004 documentation indicated the installation of a discharge line connecting the pond with the sewer, however, the current underground service diagrams for the site do not show this connection. It was reported by Defence personnel interviewed that this connection is unlikely, as the sewer main is a significant distance from the facility, while an underground stormwater drainage line passes through the facility and was considered the more likely discharge point. The discharge of the tanks and pond, was reviewed by BMA services contractor (Spotless) in mid-August 2017 as part of the pond re-lining activities proposed for upgrade in late 2017. It was identified by Spotless that a stormwater pipe (approximately 600-750 mm in diameter) flows to the west, parallel to Simpson Road, which discharges to an open swale at the eastern boundary of the Close Training Area. No connections to sewer were identified during the review. Prior to 2010, the water from the platform was directed to the sediment pond, and the water was recycled during each training activity. The practice was ceased in response to concerns associated with the hygiene and potential contaminant load within the recycled water. The sediment pond was reported to have overflowed during heavy rain, however, this was considered to have been a rare event.

The facility is predominately used by the ASO for the fire-fighting components of the various Petroleum Platoon training courses. It was reported that the courses include approximately seven 2-day fire training exercises and approximately two 8-day fire training exercises, totalling approximately 30 days of use by the ASO per year. In addition, the Current Fire Training Area is also used by the BFS, with training reported to be typically completed on a monthly to bi-monthly basis.

It was reported by Defence personnel interviewed that the ASO continued to use AFFF PFAS based foams (typically 3M AFFF or 3M Lightwater) until approximately 2010, when the current training foam products were phased in. The foams were generally stored in 20 L drums and applied using the “drum and spike” (venturi) method, with the venturi typically feeding the foam concentrate directly into the nozzle of the hose. The equipment used in the training was subsequently washed down and stored within the Petroleum Platoon – Fuel Handling Facility (Section 9.1.5), where the foam concentrates were also stored.

The current base underground service diagram indicates an underground stormwater drain running east to west through the centre of the site, with surface drainage from the platform and surrounding Current Fire Training Area directed into this service. The stormwater pipe is marked as discharging into a surface drainage path approximately 150 m west of the Current Fire Training Area, with water flowing north-west towards Jack in the Box Creek. As noted above, it was confirmed during the recent drainage review that the stormwater pipe flows towards the west and ultimately to Jack in the Box Creek. However, the pipe was identified to discharge into surface drainage (open swale) approximately 240 m west of the Current Fire Training Area, not 150 m as marked on the base service diagrams. The recent drainage review by Spotless did not identify any sewer connections. The site inspection indicated that surface water from the area appeared to drain to the...
west parallel with Simpson Road into formed drainage channels and towards Jack in the Box Creek. Some surface sheet flow may cross Simpson Road and discharge via the Petroleum Platoon – Fuel Handling Facility (Section 9.1.5).

Maunsell / CH2M HILL (2006), collected five shallow soil samples from only 0.1 m due to hard ground conditions at the time. One groundwater monitoring well (MW04) was installed to a depth of 27 m, with water encountered at approximately 25 m depth. The soil and groundwater samples were analysed for anionic surfactants with detections only reported in the groundwater sample (MW04) at 0.4 mg/L. Vantage (2010) completed a groundwater sampling event of MW04 following a reported breach of AFFF barriers within the Current Fire Training Area. No AFFF related chemicals including PFOS, PFOA or 6:2 FtS concentrations were detected at above the respective practical quantification limits (PQLs) in the groundwater sampled. The Golder 2012 investigations did not include additional sampling in this area.

**Sampling Plan**

The sample locations are presented on Figure 11E, 12E and 13E. For further details Appendix D presents the sampling completed within the area of interest.

**Soil Results**

The source area is within a commercial / industrial land use area (Figure 3). There were no reported PFAS exceedances of the commercial / industrial human health soil guidance values.

Exceedances of the interim indirect commercial / industrial (0.14 mg/kg) soil ecological guidance values for PFOS were noted.

**Groundwater Results**

There were no reported PFAS exceedances of the human health guidance values.

**Surface Water and Sediment Results**

Surface water samples were not able to be collected from within the source area, except for 0445S_SW336, as the drainage channels were observed to be dry. The surface water sample collected from the lined pond at 0445S_SW336 reported:

- A concentration of 50.7 µg/L of PFOS+PFHxS, which exceeded the human health drinking water (0.07 µg/L) and recreational water (0.7 µg/L) guidance values.
- A concentration of 1.2 µg/L of PFOA, which exceeded the human health drinking water (0.56 µg/L) guidance values.
- A concentration of 1.03 µg/L of 6:2 FtS which exceeded the LOR.

Drainage channels within the Source Area 6 were frequently observed to be dry during the investigation. As the drain was dry, terrestrial ecological species may be present in the drain. And drain maintenance activities associated with fire training infrastructure are also likely to occur within this area. Therefore, the reported sediment concentrations have been compared against both the human health and ecological commercial / industrial soil guidance values.

There were no reported PFAS exceedances of the commercial / industrial human health soil guidance values or the interim indirect commercial / industrial ecological soil guidance values for the sediment sample analysed from a drainage channel (SD335). A sediment sample from the lined pond (SD336) was not able to be collected.
9.1.7 Source Area 7 – Old Fire Station – Building 421 (RMV0037) [South Bandiana]

The old Base Services Fire Station (Building 421) is located in the southern, central portion of South Bandiana and is identified as Defence CSR site reference RMV0037 (Figure 10, Source Area 7). A fenced compound located to the south of Building 421 was observed during site inspection to contain a wash-point and a large diameter (~1.8 m) groundwater extraction bore formerly used for pump lift testing. It was also reported by HLA (2006) that two abandoned underground storage tanks (USTs), SBAN12 and SBAN13, are located south-west of Building 421. Golder (2012) undertook geophysical survey using ground penetrating radar (GPR), however, there were no apparent subsurface structures detected by GPR in the survey area representative of a UST. It is understood that the old Fire Station building is currently used to store ASLO field equipment.

Photograph 16: Area to the west of the fenced compound used for fire training activities by Base Fire Services (facing north-east). Blackened and bare earth patches are visible in the foreground and the Old Fire Station (Building 421) is visible in the background.

Interviews with former and current BFS personnel indicated that use of the Fire Station ceased in 1993 when the current Fire Station at East Bandiana was constructed (Section 9.1.12). It was reported that fire training activities were historically undertaken to the west of the fenced compound in a grassed area which was historically fenced off. Fire training activities were undertaken in a pit using petrol, paint, aviation fuel and other flammable liquids to fuel the fire, and 20 L drums of AFFF fitted with venturi pumps to extinguish the fire. Fire training activities using AFFF based extinguishers were also undertaken to the west of the fenced compound. A number of bare earth and blackened earth patches were observed to the west of the fenced compound during the site walkover. It was further reported by Army Fire Services personnel that fire training included demonstrations of ‘foam blankets’ across the ground surface to the south and west of the fenced compound to provide evidence of being able to smother a fire if required.

Fire training activities were reportedly undertaken on a fortnightly basis, with the quantity of AFFF being used / allocated dependant on the number of personnel posted to the Old Fire Station. It was reported that approximately 28 personnel were posted to the Old Fire Station prior to the 1990s and that there was an allowance of approximately one drum of AFFF per person per month. It is considered likely by the Defence personnel interviewed that the main AFFF product used was 3M Lightwater, based on the facility being used prior to 1993. It was reported by site personnel that Ansulite AFFF was used post-1993.

Following completion of fire training activities, it was reported that the equipment was flushed in the same general area where training was undertaken. Fire trucks were washed down within the wash point located in the eastern portion of the fenced compound. It was reported by site personnel that, on occasion, vehicles in the wash point were washed using AFFF. Truck repairs were historically undertaken at East Bandiana.

The Army Fire Services personnel interviewed did not report any major incidents to which they were required to respond where AFFF was used.

Observations during the site inspection indicated that surface water from the area to the west and south of the fenced compound drains to the west into formed drainage channels and towards Jack in the Box Creek. Site service plans indicated that the wash point drains to stormwater pipes and subsequently into formed drainage channels and towards Jack in the Box Creek.
Golder (2012) drilled four soil bores within the fenced compound and one adjacent to the western wall of Building 421. Shallow soil samples collected at 0.1 m bgl from two boreholes (BH108 along the eastern edge of the fenced compound and BH109 adjacent to the western wall of Building 421) were analysed for PFAS. Concentrations of PFOS were 1.08 mg/kg in BH108 and 1.50 mg/kg in BH109, and concentrations of PFOA were 0.0027 mg/kg in BH108 and 0.0014 mg/kg in BH109. Groundwater wells were not installed in this area during the prior 2012 investigation. There has been no known sampling in the area where fire training activities were undertaken.

**Sampling Plan**
The sample locations are presented on Figure 11F, 12F and 13F. For further details Appendix D presents the sampling completed within the area of interest.

**Soil Results**
The source area is within a commercial / industrial land use (Figure 3). There were no reported PFAS exceedances of the commercial / industrial human health soil guidance values.

Exceedances of the interim indirect commercial / industrial (0.14 mg/kg) soil ecological guidance values for PFOS were noted.

**Groundwater Results**
The PFAS exceedances of the human health guidance values included:

- The groundwater sample collected from 0445S_MW319 located to the north-west (hydraulic down-gradient) of the fire station reported concentrations of 0.31 µg/L of PFOS+PFHxS which exceeded drinking water guidance values (0.07 µg/L).

- The groundwater sample collected from 0445S_MW321 located to the north-west (hydraulic down-gradient) of the fire station reported concentrations of 7.65 µg/L of PFOS+PFHxS which exceeded drinking water (0.07 µg/L) and recreational water (0.7 µg/L) guidance values.

**Surface Water and Sediment Results**
Surface water samples were not able to be collected from within Source Area 7 as the drainage channels were observed to be dry.

There were no reported exceedances of the commercial / industrial human health soil guidance values for PFAS in sediment.

The drainage channels within the source area were frequently observed to be dry during the investigation, therefore, the reported sediment sample concentrations have been compared against the commercial / industrial soil guidance values for ecological purposes.

There were no reported PFAS exceedances of the interim indirect commercial / industrial ecological soil guidance values.

### 9.1.8 Source Area 8 – Original Fire Station – Corner of Anderson Road and Donegon Road [South Bandiana]

It was reported that the Original Fire Station was positioned on the south-eastern corner of Anderson Road and Donegon Road (Figure 10, Source Area 8). While no details were provided on former activities, it is possible that the activities which occurred at the Original Fire Station would have been similar to those undertaken at the Old Fire Station (Source Area 7) (Section 9.1.7) given the similar era of training. Currently, the area is open grass with scattered trees and a small barbeque area. No evidence of previous fire training activities was evident in the area during the site inspection.
A review of historical aerial imagery between 1969 and 2003 (Appendix E) also did not identify buildings in this area which may have indicated the presence of a former fire station. It is noted that the aerals reviewed between 1969 and 1991 identified a building on the corner of Anderson Road and Lord Road (to the south of the current football field), as well as a building further to the south along Anderson Road. These buildings have since both been demolished and as such, were not able to be inspected. The review of aerial imagery also did not identify potential pits in the vicinity of buildings near the Anderson Road and Donegon Road intersection where fire training may have been undertaken.

**Sampling Plan**

The sample locations are presented on Figure 11F and 12F. For further details Appendix D presents the sampling completed within the area of interest.

**Soil Results**

The source area is within a residential and open space land use area (Figure 3). There were no reported PFAS exceedances of the open space or low density residential human health soil guidance values. There were also no exceedances of the interim direct open space (1 mg/kg) or indirect residential / parkland (0.01 mg/kg) ecological soil guidance values.

**Groundwater Results**

There were no reported PFAS exceedances of the human health water guidance values.

### 9.1.9 Source Area 9 – POL Building 490 (RMV0006) [South Bandiana]

The Petroleum, Oils and Lubricants (POL) point is located to the west of the main entrance to South Bandiana (Figure 10, Source Area 9). This POL is identified as Defence CSR site reference RMV0006. This is the main transport refuelling depot for the site and contains three self-bunded (double skinned) above ground storage tanks (ASTs) and an in-ground puraceptor installed during 2014. The ASTs comprise two diesel ASTs with maximum fill volumes of 69,200 L and one unleaded petrol AST with a maximum fill volume of 55,980 L. Previous monitoring wells BH112, MB03-MWEX1 and BH120 (also referred to as SMW01, SMW02 and SMW04 respectively) were destroyed during the POL refurbishment works. Two new wells (SMW07 and SMW08) were subsequently installed in August 2014 (Vantage 2014) to the north and south of the puraceptor.

The four USTs (SBAN05 to SBAN08 inclusive) in a tank farm formerly to the north-east of the canopy are likely to have been removed in 2014 during the refurbishment works based on observations during the site inspection and reviews of aerial imagery. Two tanks formerly contained diesel (tanks 3 and 4 [SBAN07 and SBAN08]) and two formerly contained unleaded petrol (tanks 1 and 2 [SBAN05 and SBAN06]). Golder (2012) reported that the tanks were partly recessed into the ground and were all noted to have a safe fill level of 68,500 L each.

A 90 L AFFF fire extinguisher was observed during the site inspection and site personnel indicated that a foam locker may have been present at the POL historically. A foam locker was described as generally...
containing two to four 20 L drums of AFFF and hoses which could be used in the event of a fuel fire. Site personnel interviewed did not indicate any instances where use of the foam locker was required.

Stormwater runoff from the POL Point is captured in stormwater drains or open spoon drains, which drain to the stormwater ponds (wetlands) at the entrance to South Bandiana.

While there have been numerous environmental investigations at the POL, there has been no known analysis for PFAS in soil or groundwater.

**Sampling Plan**

The sample locations are presented on Figure 12D. For further details Appendix D presents the sampling completed within the area of interest.

**Groundwater Results**

The PFAS exceedances of the human health groundwater guidance values included:

- The groundwater sample collected from 0445S_BH111 located up-gradient of the fuel infrastructure reported concentrations of 1.70 µg/L of PFOS+PFHxS which exceeded drinking water (0.07 µg/L) and recreational water (0.7 µg/L) guidance values. It is noted that BH111 is installed in perched water and is nested within BH157.

**9.1.10 Source Area 10 – Former Unit Training Area – Between Warehouse 1 and 2 [North Bandiana]**

Interviews with site personnel indicated that military unit fire training was undertaken on the open ground between Warehouses 1 and 2 on North Bandiana (Figure 10, Source Area 10). It was indicated that the area was also used for burning bulky wood wastes, hence became the point for fire training activities. The time frame, type of AFFF used and magnitude of the fire training were not able to be provided. However, it was considered by the Defence personnel interviewed that the training generally occurred in the order of once a year.

The site walkover of the area did not identify any clear indications of past fire training activities with the exception of some minor areas with poor grass cover. The area was gently sloping to the south and two open surface water drains passed through the area. Surface water runoff from the area is likely to drain to the south and enter the main drainage channel passing through North Bandiana, which flows through a residential estate (part of the Killara Township), before ultimately entering the Kiewa River (Figure 2).

**Sampling Plan**

The sample locations are presented on Figure 11G, 12G and 13G. For further details Appendix D presents the sampling completed within the area of interest.
Soil Results
Source Area 10 is within a commercial / industrial land use area (Figure 3). There were no reported PFAS exceedances of the commercial / industrial human health soil guidance values or the interim indirect commercial / industrial ecological soil guidance values.

Groundwater Results
There were no reported PFAS exceedances of the human health guidance values.

Surface Water and Sediment Results
Surface water samples were not able to be collected from within the source area as the drainage channels were observed to be dry.

There were no reported exceedances of the commercial / industrial human health soil guidance values for PFAS in sediment.

The drainage channels within the source area were frequently observed to be dry during the investigation, therefore, the reported sediment sample concentrations have been compared against the commercial / industrial soil guidance values for ecological purposes.

There were no reported exceedances of the interim indirect commercial / industrial ecological soil guidance values for PFAS in sediment.

9.1.11 Source Area 11 – Fire Extinguisher Disposal – Warehouse 13 [North Bandiana]
The area surrounding Warehouse 13 (Building 78), located along the southern boundary of North Bandiana (Figure 10, Source Area 11), was reported during interviews with Defence personnel to have been used to empty expired fire extinguishers. Site personnel formerly working in disposals indicated that the extinguishers were emptied near the warehouse loading dock to the east and near an annex to the north.

Observations during the site inspection did not indicate any formal drainage channels from the grassed areas reportedly used to empty fire extinguishers. The grassed area to the east of Warehouse 13 generally slopes towards the north to north-east, and the area near the annex slopes to the north.

Both areas drain to a large formed channel (unnamed creek) directly to the north of Warehouse 13 which drains through North Bandiana to the north-east, towards Whytes Road and through a residential estate and into the Kiewa River. A smaller formed drainage channel was observed running from the north-eastern corner of Warehouse 13 to the larger drainage channel, however, it is considered unlikely from site observations that surface water runoff from either grassed area drained to this channel prior to entering the main channel.

There has been no known soil, surface water or groundwater investigations in the vicinity of Warehouse 13. However, soil sampling has been undertaken surrounding Warehouses 1, 7, 9, 10, 11, 12, 28 by GHD (2007) and within Warehouses 6, 7, 9, 10, 11, 12, 18 and 28 by Noel Arnold & Associates (2011) for a range of
contaminants including heavy metals, organochlorine pesticides (OCPs), organophosphorus pesticides (OPPs), polychlorinated biphenyls (PCBs), VOCs, PAHs, phenols, TRH and BTEX. GHD (2007) also collected one surface water sample to the north-east of Warehouse 7 for analysis of dissolved metals, OCPs, OPPs, phenols, BTEX and TRH.

**Sampling Plan**

The sample locations are presented on Figure 11H, 12H and 13H. For further details Appendix D presents the sampling completed within the area of interest.

**Soil Results**

The source area is within a commercial / industrial land use (Figure 3). There were no reported PFAS exceedances of the commercial / industrial human health soil guidance values or interim indirect commercial / industrial ecological soil guidance values.

**Groundwater Results**

There were no reported PFAS exceedances of the human health water guidance values.

**Surface Water and Sediment Results**

The surface water sample collected at 0445S_SW369 reported 0.0895 µg/L of PFOS+PFHxS which exceeded the human health drinking water (0.07 µg/L) guidance values.

There were no reported exceedances of the commercial / industrial human health soil guidance values for PFAS in sediment.

The drainage channels within the source area were frequently observed to be dry during the investigation, therefore, the reported sediment sample concentrations have been compared against the commercial / industrial soil guidance values for ecological purposes.

There were no reported PFAS exceedances of the interim indirect commercial / industrial ecological soil guidance values.

**Source Area 12**

Building 100 was identified as an area where foams were historically stored, and potentially used (Figure 10, Source Area 12). The building is where Heavy Armoured Vehicle maintenance training occurs, and the facility included a small POL located to the east (Building 598). Interviews with site personnel noted that the building previously had a “foam locker”, which was described as a steel cabinet approximately 1.5 m tall and 2.5 m wide containing between four and five 20 L drums of foam concentrate along with the associated fire-fighting equipment. No major incidents were reported in this area; however, it was noted that some foam training activities may have occurred. This training is inferred to have most likely been unit training activities or similar. The time frame, type of AFFF used and magnitude of the fire training were not able to be provided, nor was the former position of the foam locker.
Observations during the site walkover of the area did not identify any clear indications of past fire training activities, and the foam locker was not apparent. The POL did not appear to contain significant quantities of fuels, with only 200 L drums stored and the AST identified during the Golder 2012 investigations was no longer present. The previous investigation included the collection and analysis of soil samples from adjacent to the POL, however, the samples were not analysed for PFAS compounds.

Drainage from the area will flow to the south via either the kerb / gutter and piped network, or within open channels. The water discharges into the main drainage channel passing through the south-eastern portion of North Bandiana, before ultimately entering the Kiewa River after passing through a residential area, which is part of the Killara Township (Figure 1).

**Sampling Plan**

The sample locations are presented on Figure 11G, 12G and 13G. For further details Appendix D presents the sampling completed within the area of interest.

**Soil Results**

The source area is within a commercial / industrial land use (Figure 3). There were no reported PFAS exceedances of the commercial / industrial human health soil guidance values or the interim indirect commercial / industrial ecological soil guidance values.

**Groundwater Results**

There were no reported PFAS exceedances of the human health water guidance values with the exception of:

- The concentration of PFOS+PFHxS (0.09 µg/L) in the groundwater sample collected from 0445N_MW342, located hydraulic down-gradient of Building 100, which exceeded drinking water guidance values (0.07 µg/L).

**9.1.12 Source Area 13 – Fire Station – Current (RMV0002) [East Bandiana]**

The Current Fire Station (Defence CSR site reference RMV0002) was constructed in 1993 and is part of East Bandiana, however, the station is fenced off from the main operations on East Bandiana and is accessed from Whytes Road. The fire station comprises the main building (Building 411) which houses fire trucks and office space, two storage sheds including one to the east (Building 588) and one to the west (Building 956) of the main building, and a vehicle wash point with an associated triple interceptor located to the west of the main building.

Interviews with site personnel at the fire station and a review of historical reports indicates that AFFF products were historically used in a number of areas around the fire station, including:
A fire training area was reported to be located in the vicinity of the fire station by GHD (2003, cited by Golder 2012). It was reported by GHD that the general fire training area comprised a large, open, unsealed area which was flat and sparsely vegetated. GHD (2003, cited by Golder 2012) reported that fire training activities were undertaken in an earthen bund, approximately 0.8 to 1 m high. The base of this bund comprised compacted silty clays. The actual position of the training area, was not provided by GHD, however based on description, the fire training area was likely located directly to the north of the fire station. This area was formerly grassed, however, a car parking area was constructed across this potential former training area during the 2014 redevelopment works.

The grassed area to the west of the vehicle wash point was reportedly used for equipment testing (EarthTech, 2005) and training exercises (Maunsell / CH2M HILL, 2006). EarthTech (2005) indicated the equipment testing using AFFF was stopped in approximately 2004. Monitoring well 0445E_MW06-A is located within this area.

AFFF was historically used in the concrete area near the wash point which drained to a triple interceptor trap which discharged to stormwater. It was reported by site personnel that the triple interceptor trap had since been replaced.

Maunsell / CH2M HILL (2006) conducted an environmental investigation in the area surrounding the fire station including the installation of three groundwater monitoring wells (MW05 to MW07), six hand augers (R002/HA01 to R002/HA06) and collection of one sediment sample (R002/SED16) from an open drain to the north-east of the fire station. The samples collected were all analysed for anionic surfactants with detections in groundwater at MW06 (0.3 mg/L), and detections in soil from surface samples collected at 0.1 m bgl from R002/HA01 (7 mg/kg), R002/HA03 (5 mg/kg) and R002/HA04 (6 mg/kg).

Further environmental investigations were undertaken by Golder (2012) which included seven shallow soil samples (SS015 to SS021) to depths of 0.1 m bgl in the area directly to the north of the fire station. Concentrations of PFOS were reported in each of the seven soil samples with concentrations ranging from 0.026 mg/kg to 3.72 mg/kg. Concentrations of PFOA were reported in two samples. The existing groundwater wells (MW05 to MW07) were sampled with concentrations of PFOA (0.11 to 4.7 µg/L) and PFOS (1.24 to 11.5 µg/L) reported in all samples. The highest concentrations were observed at MW07 located to the north-east of the fire station. A detection of 6:2 FtS (0.2 µg/L) was also reported at MW07. It is noted that both
MW05 and MW07 were unable to be located during the Golder inspection in July 2017 and were likely destroyed in 2014 during construction of the carpark.

Stormwater runoff from the area enters pits located predominantly to the east and north-east of the main building. Stormwater from the area likely exits East Bandiana at the outlet located along the drainage channel to the north-east of the test track facility and eventually enters the Kiewa River. However, it is noted that a number of abandoned stormwater pipes are identified on the site service diagrams, as such it is possible that stormwater runoff from the fire station area may have historically exited the East Bandiana at the outlet between Building 592 and 942 via stormwater pipes discharging to the Kiewa River prior to the 2014 redevelopment (Figure 13P).

**Sampling Plan**
The sample locations are presented on Figure 11I, 12I and 13I. For further details Appendix D presents the sampling completed within the area of interest.

**Soil Results**
The source area is within a commercial / industrial land use (Figure 3). There were no reported PFAS exceedances of the commercial / industrial human health soil guidance values.

Exceedances of the interim indirect commercial / industrial (0.14 mg/kg) soil ecological guidance values for PFOS were noted.

**Groundwater Results**
All groundwater samples collected within the source area reported exceedances of the human health guidance values:

- Groundwater samples collected from 0445E_BH01 (3.38 µg/L), 0445E_BH02 (of 6.8 µg/L), and 0445E_MW350-S (4.24 µg/L) located down- to cross-gradient of the fire station, and 0445E_MW06-A (1.37 µg/L) located up-gradient of the fire station reported concentrations of PFOA which exceeded drinking water guidance values (0.56 µg/L).

- Groundwater samples collected from 0445E_BH01 (96.2 µg/L), 0445E_BH02 (118 µg/L), and 0445E_MW350-S (90.2 µg/L) located down- to cross-gradient of the fire station, and 0445E_MW06-A (26.5 µg/L) located up-gradient of the fire station reported concentrations of PFHxS+PFOS which exceeded drinking water (0.07 µg/L) and recreational water (0.7 µg/L) guidance values. Groundwater well 0445E_MW350(D) located to the east (inferred hydraulic down-gradient) of the fire station reported a concentration of 0.63 µg/L of PFHxS+PFOS which only exceeded drinking water guidance values (0.07 µg/L).

**Surface Water and Sediment Results**
Surface water samples were not able to be collected from within the source area as the drainage channels were observed to be dry.

There were no reported exceedances of the commercial / industrial human health soil guidance values for PFAS in sediment.

The drainage channels within the source area were frequently observed to be dry during the investigation, therefore, the reported sediment sample concentrations have been compared against the commercial / industrial soil guidance values for ecological purposes.

There were no reported PFAS exceedances of the interim indirect commercial / industrial ecological soil guidance values.
9.1.13 Source Area 14 – Former Unit Training Building 592 [East Bandiana]

Interviews with site personnel indicated that unit fire training was undertaken on the open ground adjacent to Building 592 (Figure 10, Source Area 14). The time frame, type of AFFF used, frequency and magnitude of the fire training were not able to be provided.

A site walkover of the areas did not identify any clear indications of past fire training activities with the exception of some minor areas with poor grass cover. The area was primarily flat and ponded surface water was observed. Surface water runoff (if any) from the area next to Building 592, is likely to drain to the east and discharge into the Kiewa River.

Sampling Plan

The sample locations are presented on Figure 11J, 12J and 13J. For further details Appendix D presents the sampling completed within the area of interest.

Soil Results

The source area is within an open space land use (Figure 3). There were no reported PFAS exceedances of the open space human health soil guidance values, or the interim direct or indirect residential / parkland ecological soil guidance values.

Groundwater Results

All groundwater samples collected within the source area reported exceedances of the human health guidance values:

- Groundwater samples collected from 0445E_MW42 (0.7 µg/L) and 0445E_MW43 (1.09 µg/L) located within the south-eastern portion of the source area reported concentrations of PFOA which exceeded drinking water guidance values (0.56 µg/L).

- Groundwater samples collected from 0445E_MW09 (9.92 µg/L), 0445E_MW16 (11.6 µg/L), 0445E_MW35 (12.1 µg/L), 0445E_MW42 (15.4 µg/L) and 0445E_MW43 (32.0 µg/L) located along the eastern boundary and through the centre of the source area reported concentrations of PFHxS+PFOS which exceeded drinking water (0.07 µg/L) and recreational water (0.7 µg/L) guidance values.

The groundwater samples collected from monitoring wells considered to be immediately up-gradient of receiving surface water bodies, including MW16 (7.35 µg/L) and MW35 (3.97 µg/L), exceeded the 90% species protection guidance value (2.0 µg/L), 95% species protection guidance value (0.13 µg/L) and 99% species protection guidance value (0.00023 µg/L) for freshwater.

Surface Water and Sediment Results

Surface water samples were not able to be collected from within the source area as the drainage channels were observed to be dry.

There were no reported exceedances of the open space human health soil guidance values for PFAS in sediment.

The drainage channels within the source area were frequently observed to be dry during the investigation, therefore, the reported sediment sample concentrations have been compared against open space soil guidance values for ecological purposes.

There were no reported PFAS exceedances of the interim direct or indirect residential / parkland ecological soil guidance values.
9.1.14 Source Area 15 – Former Unit Training Football Field [East Bandiana]

Interviews with site personnel indicated that unit fire training was undertaken on the former football field located in the south-eastern corner of East Bandiana (Figure 10, Source Area 15). The time frame, type of AFFF used, frequency and magnitude of the fire training were not able to be provided.

A site walkover of the area did not identify any clear indications of past fire training activities with the exception of some minor areas with poor grass cover. The area was primarily flat and ponded surface water was observed. Surface water runoff (if any) is likely to drain to south-east, either towards Middle Creek (also referred to as Wodonga Creek) and ultimately enter the Kiewa River, or towards the north-east to an oxbow lake / billabong.

Sampling Plan

The sample locations are presented on Figure 11K and 12K. For further details Appendix D presents the sampling completed within the area of interest.

Soil Results

The source area is within an open space land use area (Figure 3). There were no reported PFAS exceedances of the open space human health soil guidance values, or the interim direct or indirect residential / parkland ecological guidance values.

Groundwater Results

The groundwater sample collected at 0445E_MW354 located in the centre of the source area, and considered to be immediately up-gradient of receiving surface water bodies, reported the following concentrations which exceeded adopted guidance values:

- A concentration of 0.27 µg/L of PFHxS+PFOS which exceeded human health drinking water guidance values (0.07 µg/L).
- A concentration of 0.10 µg/L of PFOS which exceeded the ecological guidance values for 99% species protection (0.00023 µg/L) for freshwater.

9.2 On-base Sensitive Receptors

9.2.1 Bandiana Primary School [South Bandiana]

Bandiana Primary School is located to the east of the golf course in the eastern portion of South Bandiana. The main features include a carpark, a number of buildings / classrooms and two large playing fields. The school is located on-base within the Defence property and leased to the Victorian Education Department. The area generally slopes to the north to north-west with surface water likely draining towards ponds within the golf course. There is no bore or surface water collection on the property.

During the investigation, information was provided by the Department of Education representative regarding food production and play activities at the Bandiana Primary School. The evaluation of this information
concluded that the school activities are consistent with the assumptions used in the derivation of the residential land use screening value.

**Sampling Plan**
The sample locations are presented on Figure 11L. For further details Appendix D presents the sampling completed within the area of interest.

**Soil Results**
Bandiana Primary School is a sensitive land use area (Figure 2). There were no reported PFAS exceedances of the low density residential human health soil guidance values or interim indirect low density residential ecological guidance values.

**9.2.2 Bandiana Neighbourhood House [North Bandiana]**
The Bandiana Neighbourhood House is located in the south-western portion of North Bandiana. The main features include a carpark, one building and an outdoor fenced play area. The area generally slopes to the south with surface water likely draining towards the open drainage channels and into the unnamed creek which flows into the Kiewa River.

**Sampling Plan**
The sample locations are presented on Figure 11M. For further details Appendix D presents the sampling completed within the area of interest.

**Soil Results**
The on-base Bandiana Neighbourhood House is considered a sensitive land use area (Figure 2). There were no reported PFAS exceedances of the low density residential human health soil guidance values or interim indirect low density residential ecological guidance values.

**9.3 On-base General Coverage**
General coverage sampling was undertaken across the base to assess background conditions, boundary conditions, migration from the abovementioned source areas, and potential contribution from diffuse sources.

A description of the diffuse sources identified during the site inspection are detailed in Section 9.3.1 below, and the investigation results for the general coverage sampling are presented according to the respective drainage catchment and base, including:

- South Bandiana: Jack in the Box Creek catchment.
- South Bandiana: Kiewa River catchment.
- North Bandiana: Kiewa River catchment.
- East Bandiana: Kiewa River catchment.

The investigation results for the Bears Hill Preliminary Sampling are presented in Section 9.3.5.

**9.3.1 Diffuse Sources**

**Incidental Use and Storage**
The interviews undertaken with site personnel across South, East and North Bandiana identified a number of areas where the incidental use of AFFF may have occurred and locations where AFFF was stored (Figure 10).
These areas are listed below:

### South Bandiana:
- Building 378 located in the central-eastern portion of south Bandiana was identified as a former Q-Store. The site interviews indicated the AFFF foams were supplied by the various Q-Stores, hence, were likely used to store varying quantities of AFFF products. A vehicle wash point was also reported at the front (north-east) of the building. Golder (2012) reported that a former covered vehicle wash was observed to the east of Building 378 (Building 644).
- It was reported that a former vehicle / truck wash point (Building 895) was located to the south of the museum (Building 307).
- Golder (2012) identified vehicle wash bays associated with the transport service station (Building 495).
- It was reported during interview with Defence personnel that Buildings 348/350 (the former Austen Building) and 378 were a Q-Stores, however, further information was not able to be provided.
- It was also reported during interview with Defence personnel that ad-hoc use of the foams also occurred across the base for either training or display purposes. This included occasionally deploying foams on the on-base school grounds.

### North Bandiana:
- It was reported that Warehouse 28 (Building 67) was formerly used to contain chemicals and extinguishers. Further details were not able to be provided, however, Golder (2012) noted that the Warehouse was used to store paint. The warehouse has since been demolished.
- Site interviews with Defence indicated Building 441 in the central-northern portion of North Bandiana is the Q-Store for Albury Wodonga Military Area.
- A former Q-Store was identified during the site inspection at the entrance to North Bandiana to the south east of the current Post Office.

### East Bandiana:
- It was reported during interviews with Defence personnel that fire trucks were serviced in the former 4 Shop and 5 Shop. These workshops have since been demolished and the area is currently used as the EBW8 Hardstand. It was also reported during interviews that the fire trucks may have been washed in the steam clean bay (Building 605).
- Building 910 in the south-eastern portion of East Bandiana is currently used as the hazardous parts storage compound.
- Buildings 853, 912 and 913 are used as a POL storage facility, and hence may have contained AFFF-based fire extinguishers.
- Building 42 (Engine Test House) and Building 854 (the Truck Dyno Facility), located in the southern portion of the site, reportedly contain a 90 L foam fire extinguisher.

The areas listed above where incidental use of AFFF may have occurred or AFFF may have been stored were not directly targeted for sampling, and rather these areas were assessed through contributions to samples collected from general coverage sampling locations.
Active and Abandoned Sewerage Services

It has been recognised that active and abandoned sewerage services can act as diffuse sources of contamination, particularly when either licensed or unlicensed discharges of contaminated wastes occur via these networks. Sewage services across the BMA flow into the NEW sewage treatment network. Additionally, Defence hold several commercial Trade Waste Agreements (TWA) with North East Water for the discharge of trade wastes via the sewer network.

Given the source investigations have identified a potential direct connection with the sewer from the Current Fire Training Area (Source Area 6), and the identification of several wash down bays where vehicles using AFFF have historically been washed out (Source Areas 5, 7 and 13), there is potential for the sewerage network to be acting as a diffuse source across the bases through potential leakage and/or preferential flow.

A summary of the sewerage network at South, North and East Bandiana is provided below.

South Bandiana

The site service diagrams generally indicate that the sewerage network flows from south to north across the developed portion of the South Bandiana (i.e. central South Bandiana), to a larger sewerage pipe which flows south-east along the rail siding and underneath the Murray Valley Highway to North Bandiana. The South Bandiana sewerage network joins the North Bandiana network to the south of Warehouse 1 (Building 82).

North Bandiana

Based on the site service diagrams provided the active sewerage system in the southern portion of North Bandiana, associated with Warehouse 5, 8, 13, 14, 15, 16 and 17, drains to a pit to the west of Warehouse 16 and is pumped approximately 220 m to the north where it connects to the sewerage system associated with the northern portion of North Bandiana. The sewerage system then drains towards the eastern boundary of North Bandiana (towards Whytes Road) where it connects to the municipal sewerage system maintained by North East Water. It is understood that a program of sewer main upgrades was undertaken in the late 1990s to replace some aged pipes with polyvinyl chloride (PVC) pipes (Hyder, 1998).

The abandoned sewerage services appeared to be connected to pits associated with active sewerage service system. A number of abandoned pipes were identified on the site service plans including:

- Approximately 190 m of pipe to the west of Warehouse 14 (Building 76).
- Approximately 120 m of pipe to the north-west Warehouse 16 (Building 70).
- Approximately 140 m of pipe north-east of Warehouse 16 (Building 70).
- Approximately 130 m of pipe to the west of the Bandiana Neighbourhood House (Building 593).

East Bandiana

Based on the site service diagrams provided the active sewerage system at East Bandiana appears to flow towards the northern corner of the site where it connects to the municipal sewerage system maintained by North East Water. The site service diagrams did not provide any indications of abandoned pipes which connected to the North Bandiana sewerage network.

9.3.2 South Bandiana: Drainage to Jack in the Box Creek Catchment

The Jack in the Box Creek catchment is situated in the western portion of South Bandiana. Based on the groundwater elevation data and surface water drainage channels, the Jack in the Box Creek catchment receives groundwater and surface water drainage from Source Areas 1 to 4, 6, and 7, groundwater from Source Area 5 and surface water from the western portions of Source Area 5 (Figures 6A and 7A).
**Sampling Plan**

The sample locations are presented on Figure 11A to 11F, 12A to 12F, and 13A to 13F. For further details Appendix D presents the sampling completed.

**Soil Results**

The sampling locations are identified on Figures 11A, 11B, 11D and 11F and analytical results are presented in Table H.

These areas at South Bandiana (Jack in the Box Creek catchment) are within open space land use areas (Figure 3). There were no reported PFAS exceedances of the open space human health soil guidance values.

Exceedances of the interim direct open space (1 mg/kg) and indirect residential / parkland (0.01 mg/kg) soil ecological guidance values for PFOS were noted.

**Groundwater Results**

The sampling locations are identified on Figures 12A to 12F and analytical results are presented in Table I. The PFAS exceedances of the human health guidance values included:

- The groundwater sample collected from 0445S_MW312 (Figure 12A) located along the northern boundary of South Bandiana reported concentrations of 0.12 µg/L of PFOS+PFHxS which exceeded drinking water guidance values (0.07 µg/L).

**Surface Water and Sediment Results**

The sampling locations are identified on Figures 13A, 13B, 13D and 13F and analytical results are presented in Tables F and G.

Surface water samples collected from South Bandiana (Jack in the Box Creek catchment) reported concentrations which exceeded adopted human health guidance values. This includes surface water samples collected from 0445S_SW308 (0.118 µg/L), 0445S_SW323 (1.42 µg/L), 0445S_SW324 (2.03 µg/L), 0445S_SW332 (4.45 µg/L), 0445S_SW448 (2.38 µg/L) reported concentrations PFOS+PFHxS which exceeded drinking water (0.07 µg/L) and/or recreational water (0.7 µg/L) guidance values.

The surface water samples collected from 0445S_SW308 (Figure 13B) and 0445S_SW323 (Figure 13A) were compared to ecological guidance values for 95% species protection and 99% species protection respectively. Surface water sample 0445S_SW308 (0.028 µg/L) reported concentrations of PFOS which exceeded the 95% species protection guidance value (0.13 µg/L). Surface water sample 0445S_SW323 (1.13 µg/L) reported concentrations of PFOS which exceeded the 99% species protection guidance value (0.00023 µg/L), as well as the 95% species protection guidance value (0.13 µg/L).

There were no reported PFAS exceedances of the open space human health soil guidance values for sediment samples.

The drainage channels within the area were frequently observed to be dry during the investigation. Water was consistently observed in a ‘wetland’ located along a portion of the drainage line running north-west to south-east along the northern perimeter of the Close Training Area, and a dam located to the north-east of Source Area 2. Given that water was consistently observed within the ‘wetland’ along the drainage channel (location 0445S_SD323) and the dam (location 0445S_SD308), results were screened against the LOR for ecological purposes.

Sediment locations frequently observed to be dry reported exceedances of the interim indirect residential / parkland (0.01 mg/kg) soil ecological guidance values for PFOS. PFOS was also detected above the LOR at locations with consistent water coverage.
9.3.3 South & North Bandiana: Kiewa River Catchment

The eastern portion of South Bandiana drains via stormwater ponds (wetlands) at the base entrance to an unnamed creek which flows through North Bandiana. A series of open drainage channels across North Bandiana also drain to the unnamed creek. The unnamed creek exits North Bandiana at Whytes Road to the east and flows into the Kiewa River.

Based on the groundwater elevation data and surface water drainage channels, the Kiewa River catchment receives surface water drainage from Source Area 8 and 9, and portions of Source Area 5 (Figures 6A and 7A) located on South Bandiana. Groundwater flow from Source Area 5 appears to be towards Jack in the Box Creek, while Source Area 8 and 9 appear to be on, or near the groundwater divide and may contribute to either the Kiewa River or Jack in the Box Creek catchment (Section 6.6.2).

Surface water and groundwater flow from North Bandiana, including Source Area 10, 11 and 12, contributes entirely to the Kiewa River.

**Sampling Plan**

The sample locations are presented on Figure 11M to 11O, 12M to 12O, and 13G, 13H and 13L. For further details Appendix D presents the sampling completed. **Soil Results**

The sampling locations are identified on Figure 11M to 11O and analytical results are presented in Table H. South Bandiana Kiewa River catchment is an open space land use area (Figure 3). There were no reported PFAS exceedances of the open space human health, or interim direct open space or indirect residential / parkland ecological guidance values.

North Bandiana Kiewa River catchment is a combination of commercial / industrial and open space land use areas (Figure 3). There were no reported PFAS soil exceedances of the commercial / industrial or open space human health soil guidance values. There were also no exceedances of the interim indirect commercial / industrial, or interim direct open space or indirect residential / parkland ecological soil guidance values.

**Groundwater Results**

The sampling locations are identified on Figure 12M to 12O and analytical results are presented in Table I. There were no reported PFAS exceedances with the exception of the groundwater sample collected at 0445N_MW345 (Figure 12O) located along the unnamed creek, and considered to be immediately up-gradient of receiving surface water bodies, which reported the following concentrations:

- A concentration of 0.30 µg/L of PFHxS+PFOS which exceeded human health drinking water guidance values (0.07 µg/L).
- A concentration of 0.10 µg/L of PFOS which exceeded the ecological guidance values for 99% species protection (0.00023 µg/L) for freshwater.

**Surface Water and Sediment Results**

Surface and sediment samples were collected from ponds located on the South Bandiana golf course, stormwater ponds (wetlands) at the entry to South Bandiana, drainage channels across South and North Bandiana, stormwater ponds (wetlands) on North Bandiana and the unnamed creek that ultimately drains into the Kiewa River. The sampling locations are identified on Figure 13G, 13H and 13L to 13O and analytical results are presented in Tables F and G.

The PFAS exceedances of adopted human health surface water guidance values summarised below:
South Bandiana (Figure 13L, 13M and 13N): Concentrations of PFOS+PFHxS in samples 0445S_SW346 (1.95 µg/L), 0445S_SW347 (1.65 µg/L), 0445S_SW349 (2.1 µg/L), 0445S_SW350 (0.469 µg/L), 0.445S_SW351 (0.175 µg/L), 0445S_SW353 (0.439 µg/L), 0445S_SW355 (0.533 µg/L), 0445S_SW356 (0.451 µg/L), 0445S_SW357 (0.305 µg/L) and 0445S_SW360 (0.114 µg/L) exceeded the adopted drinking water guidance values (0.07 µg/L). It is noted that samples 0445S_SW346, 0445S_SW347 and 0445S_SW349 also exceeded recreational water guidance values (0.7 µg/L).

North Bandiana (Figure 13G, 13H, 13M and 13O): Concentrations of PFOS+PFHxS in samples 0445N_SW364 (0.0852 µg/L), 0445N_SW368 (0.399 µg/L), 0445N_SW370 (0.326 µg/L), 0445N_SW372 (0.232 µg/L), 0.445N_SW374 (0.34 µg/L) and 0445N_SW375 (0.29 µg/L) and 0445N_SW447 (0.108 µg/L) exceeded the adopted drinking water guidance values (0.07 µg/L).

The surface water samples collected from unlined ponds, stormwater ponds (wetlands) and where the unnamed creek exits North Bandiana were compared to ecological guidance values. The PFAS exceedances of adopted ecological surface water guidance values are summarised below:

South Bandiana (Figure 13M and 13N): Concentrations of PFOS in samples 0445S_SW346 (1.42 µg/L), 0445S_SW347 (1.09 µg/L), 0445S_SW349 (1.6 µg/L), 0445S_SW350 (0.284 µg/L), 0445S_SW353 (0.252 µg/L) and 0445S_SW355 (0.5325 µg/L) exceeded the adopted ecological guidance values including the 95% species protection (0.13 µg/L).

North Bandiana (Figure 13O): Concentrations of PFOS in sample 0445N_SW375 (0.19 µg/L) exceeded the adopted ecological guidance values of 99% species protection (0.00023 µg/L) for freshwater. Sample 0445N_SW375 also exceeded the 95% species protection guidance values (0.13 µg/L).

The sampling locations within the South and North Bandiana Kiewa River Catchment were generally observed to be inundated. Only four of 28 locations were dry at the time of sampling. Given that water was consistently observed within many of the drainage lines and water features, sediment results were screened against the LOR for ecological purposes. To assess potential risk to maintenance workers, the reported sediment sample concentrations have also been compared against the commercial / industrial and open space human health soil guidance values.

PFOS and PFOA were detected above the LOR at some sediment sample locations. Concentrations of PFAS were below the commercial / industrial or open space human health soil guidance values for sediment samples collected within the general South Bandiana or North Bandiana Kiewa River catchment area.

9.3.4 East Bandiana: Kiewa River catchment

East Bandiana drains via two main underground stormwater networks to oxbow lakes on the Kiewa River floodplain and ultimately to the Kiewa River. One stormwater discharge point is located to the east to northeast of the Test Track, and the other is located to the north of Building 592.

**Sampling Plan**

The sample locations are presented on Figures 11I, 11J and 11P for soil, 12I, 12J, 12K and 12P for groundwater, and 13I, 13J, 13K and 13P for sediment and surface water. For further details Appendix D presents the sampling completed.

**Soil Results**

The sampling locations are identified on Figure 11I, 11J and 11P and analytical results are presented in Table H.

East Bandiana: Kiewa River catchment is a combination of commercial / industrial and open space land use area (Figure 3). There were no reported PFAS soil exceedances of the commercial / industrial or open space land use area.
human health soil guidance values. There were also no exceedances of the interim indirect commercial / industrial, or interim direct open space or indirect residential / parkland ecological soil guidance values.

**Groundwater Results**

The sampling locations are identified on Figure 12I, 12J, 12K and 12P and analytical results are presented in Table I. The PFAS exceedances of the human health guidance values included:

- The groundwater samples collected from 0445E_MW12 (0.37 µg/L), 0445E_MW18 (0.31 µg/L), 0445E_MW20 (2.34 µg/L), 0445E_MW29 (0.87 µg/L), 0445E_MW30 (0.07 µg/L), 0445E_MW34 (1.59 µg/L), 0445E_MW351 (0.07 µg/L), 0445E_MW352 (0.1 µg/L), 0445E_MW353 (8.98 µg/L), 0445E_MW46 (4.31 µg/L) and 0445E_MW47 (4.27 µg/L) reported concentrations of PFOS+PFHxS which exceeded drinking water guidance values (0.07 µg/L). It is noted that samples collected from 0445E_MW20, 0445E_MW29, 0445E_MW34, 0445E_MW353, 0445E_MW46 and 0445E_MW47 also exceeded recreational water guidance values 0.7 µg/L).

The groundwater wells located within the East Bandiana: Kiewa River catchment considered to be immediately up-gradient of receiving surface water bodies include the following:

- MW351, MW352, MW18, MW20, MW21, MW34, MW46 and MW47 located along the eastern site boundary; and
- MW29 and MW30 located along the southern boundary near a drainage channel which flows directly to the Kiewa River floodplain.

PFAS exceedances of ecological water guidance values for groundwater samples collected from monitoring wells considered to be immediately up-gradient of receiving surface water bodies are summarised as follows:

- Concentrations of PFOS in the groundwater samples collected from 0445E_MW18 (0.13 µg/L), 0445E_MW20 (0.72 µg/L), 0445E_MW29 (0.38 µg/L), 0445E_MW30 (0.01 µg/L), 0445E_MW34 (0.73 µg/L), 0445E_MW351 (0.03 µg/L), 0445E_MW352 (0.02 µg/L), and 0445E_MW47 (1.99 µg/L) exceeded the 99% species protection guidance value (0.00023 µg/L) for freshwater. It is noted that locations 0445E_MW18, 0445E_MW20, 0445E_MW29, 0445E_MW34 and 0445E_MW47 also exceeded the 95% species protection guidance value (0.13 µg/L).
- Concentrations of PFOS in the groundwater sample collected from 0445E_MW46 (2.05 µg/L) exceeded the 90% species protection (2.0 µg/L), 95% species protection (0.13 µg/L) and 99% (0.00023 µg/L) species protection guidance values.
- Concentrations of PFOS in the sample collected from 0445E_MW21 were less than the laboratory reporting limit (0.01 µg/L), which is greater than the 99% species protection guidance values for PFOS in freshwater.

**Surface Water and Sediment Results**

Surface and sediment samples were collected from drainage channels and stormwater settling ponds on East Bandiana that ultimately drain into the Kiewa River. The sampling locations are identified on Figure 13I, 13J, 13K and 13P and analytical results are present in Tables F and G.

The PFAS exceedances of adopted human health surface water guidance values summarised below:

- Concentrations of PFOS+PFHxS in samples 0445E_SW381 (0.164 µg/L), 0445E_SW382 (0.14 µg/L), 0445E_SW387 (0.157 µg/L) and 0445E_SW388 (0.343 µg/L) exceeded the adopted drinking water guidance values (0.07 µg/L).
The surface water samples collected from stormwater settling ponds and where drainage channels exit East Bandiana were compared to ecological guidance values. The PFAS exceedances of adopted ecological surface water guidance values are summarised below:

- Concentrations of PFOS in samples 0445E_SW382 (maximum concentration of 0.12 µg/L), 0445E_SW387 (0.053 µg/L) and 0445E_SW388 (0.175 µg/L) exceeded the adopted ecological guidance value of 99% species protection (0.00023 µg/L) for freshwater. It is noted that sample 0445E_SW388 also exceeded the 95% species protection guidance value (0.13 µg/L).

The sampling locations within the area were generally observed to be inundated as they included the drainage channel flowing along the test track which receives stormwater runoff from East Bandiana and stormwater settling ponds. Co-located surface water samples were unable to be collected from three of the eight locations. Given that water was consistently observed within many of the drainage lines and water features, results were screened against the LOR for ecological purposes. To assess potential risk to maintenance workers, the reported sediment sample concentrations have also been compared against the commercial / industrial and open space human health soil guidance values.

PFOS and PFOA were detected above the LOR at some sediment sample locations. Concentrations of PFAS were below the commercial / industrial or open space human health soil guidance values.

9.3.5 South Bandiana: Bears Hill

Preliminary sampling was undertaken on the southern side of Bears Hill to inform the distribution of the WUS. The southern side of Bears Hill slopes to the south and south-west. Flow from this portion of South Bandiana, discharges to House Creek which drains north through Wodonga eventually discharging into the Murray River. Six surface soil samples (SS001 to SS006) and one surface water sample (SS001) were collected from the drainage lines on the southern side of Bears Hill. The sample locations are shown on Figure 11Q and 13Q.

Soil Results

Bears Hill is an open space land use area (Figure 2). There were no reported detections of PFAS in soil.

Surface Water Results

The surface water sample 0445S_SW001 collected from the drainage line on the southern side of Bears Hill reported no detections of PFAS above the laboratory LOR.

9.4 Off-Base Investigations

Off-base sampling was undertaken to assess background conditions, potential migration from the abovementioned source areas, and potential contribution from off-base sources.

The potential off-base sources identified within the investigation area are discussed within Section 9.4.1, and the investigation results for the off-base investigations are generally presented according to the respective drainage catchments, including:

- Jack in the Box Creek catchment.
- Wodonga Creek.
- Residential estate adjoining South Bandiana.
- Residential estate adjoining North Bandiana.
- Kiewa River including Middle Creek.
- Murray River.
Figures 14 to 16 present the off-base sample locations. It is noted that due to stakeholder privacy requirements, the position of some sampling locations are not identified.

### 9.4.1 Potential Off-Base Sources

PFAS have been used in a range of products and industries in Australia and internationally since the 1950s, particularly due to their unique physical and chemical properties. The NSW EPA (2017) lists the following, along with AFFF fire-fighting foams as potentially including PFAS compounds:

- Hydraulic fluids.
- Medical devices.
- Photographic and photolithographic processes.
- Coatings and coating additives.
- Shampoos.
- Denture cleaners.
- Floor polishes.
- Food packaging.
- Metal plating.
- Textile and leather products.

Within this in mind, as part of this investigation, it is important to be cognisant of what other activities are occurring in the area which have the potential of contributing to PFAS identified (if any) within the environment.

During the site inspection, the following activities were observed as notable potential off-base PFAS sources:

- Albury Airport located approximately 8.3 km north of North Bandiana (on the northern bank of the Murray River).
- The Wodonga Fire Station and the Country Fire Authority facility located approximately 2.7 km north-west of South Bandiana.
- The Wodonga West Fire Station located approximately 5.5 km north-west of South Bandiana.
- The Baranduda Waste Water Treatment Plant (WWTP) is located in close proximity to (and south of) East Bandiana. Water from the Baranduda WWTP is subsequently pumped to the West Wodonga tertiary treatment facility after which it is either re-used or discharged to the Murray River (North East Water, 2017). It is noted that North East Water has indicated that the Baranduda WWTP receives waste water from the BMA.

It is noted that two Defence properties (not included within this investigation) are located within the wider Albury Wodonga region, which include Latchford Barracks, located approximately 4 km to the east of East Bandiana, and Wirlinga, located approximately 8 km north-east on the NSW side of the Murray River.

Since approximately the 1990s Defence has divested several portions of the BMA, including parcels of land to the west of South Bandiana and east of North Bandiana. The divested land to the west, included an area identified in the previous investigations as being a former landfill (now a residential subdivision). Divested land to the east included the footprint of the former Bandiana STP (now a residential subdivision).
Both of these areas were identified during the site interviews as potential off-base PFAS sources.

In addition to the notable facilities, given the urban Wodonga environment it is expected that a level of “background” PFAS contamination will be present within the environment, therefore the investigations include the collection of several background samples to assist with distinguishing between potential base-sourced PFAS and non-base sourced PFAS (Sections 9.4.6 and 9.4.7).

9.4.2 Jack in the Box Creek

The Jack in the Box Creek catchment receives drainage from the western portion of South Bandiana. Source Areas 1 to 4, 6, 7 and portions of Source Area 5 contribute to the catchment. Sampling Plan

The sample locations are presented on Figures 14A for soil, 15A for groundwater, and 16A for sediment and surface water. For further details Appendix D presents the sampling completed.

**Soil Results**

The sample descriptions are included in Table E, and analytical results are included in Table L. Sample locations are identified on Figure 14A.

The overland flow path is generally parkland and is therefore considered to be an open space land use.

There were no reported PFAS exceedances of the open space human health guidance values. Exceedances of the interim indirect residential / parkland ecological guidance values (0.01 mg/kg) were noted at one location.

**Groundwater Results**

The monitoring well locations are identified on Figure 15A and analytical results are present in Table M.

The PFAS exceedances of the human health guidance values included:

- Concentrations of PFOS+PFHxS in sample 0445_MW360 (0.232 µg/L) and 0445_MW361 (0.296 µg/L) exceeded the adopted drinking water guidance values (0.07 µg/L).

The groundwater well located along lower Jack in the Box Creek, MW361, is considered to be immediately up-gradient of receiving surface water bodies. Concentrations of PFOS in sample 0445_MW361 (0.059 µg/L) exceeded the 99% species protection guidance values (0.00023 µg/L) for freshwater.

**Surface Water and Sediment Results**

Fourteen surface water and 12 sediment samples were collected from along Jack in the Box Creek, including two rounds of sampling from location SW/SD424. Surface water and sediment sampling descriptions are presented in Tables A and B. The sampling locations are identified on Figure 16A and analytical results are presented in Tables J and K.

The PFAS exceedances of adopted human health surface water guidance values are summarised below:

- Concentrations of PFOS+PFHxS at two locations immediately downstream of South Bandiana exceeded the adopted drinking water (0.07 µg/L) and recreational water (0.7 µg/L) guidance values including:
  - Location 0445_SW424 for both the pre-rain sample collected on 11 October 2011 (5.1 µg/L) and the post-rain sample collected on 13 October 2017 (1.33 µg/L).
  - Location 0445_SW463 (1.03 µg/L) a small pond observed to contain yabbies.

- Concentrations of PFOS+PFHxS at five locations exceeded the adopted drinking water (0.07 µg/L) guidance values including, listed in order from South Bandiana towards the Wodonga Creek confluence,
SW425 (0.222 µg/L), SW427 (0.133 µg/L), SW428 (0.213 µg/L), SW431 (0.0732 µg/L), and SW432 (0.0769 µg/L).

There were no reported exceedances of the ecological guidance values for PFOA in surface water, however, PFOS exceedances were reported in the fourteen samples collected and analysed including:

- Concentrations of PFOS at location SW424 exceeded the 90% (2 µg/L), 95% (0.13 µg/L) and the 99% (0.00023 µg/L) species protection guidance values for freshwater for the pre-rain sample (3.3 µg/L). The post-rain sample (0.706 µg/L) exceeded the 95% (0.13 µg/L) and the 99% (0.00023 µg/L) species protection guidance values for freshwater.

- Concentrations of PFOS at location SW463 (0.54 µg/L) exceeded the 95% (0.13 µg/L) and the 99% (0.00023 µg/L) species protection guidance values for freshwater.

- Concentrations of PFOS in the remaining eleven samples exceeded the 99% (0.00023 µg/L) species protection guidance values for freshwater with concentrations ranging from 0.0038 µg/L (SW434) to 0.114 µg/L (SW425).

To assess potential risk to people who may encounter sediments, such as maintenance workers or those involved in recreational activities, the reported sediment sample concentrations have been compared against the open space human health soil guidance values. As there are no ecological guidance values for PFAS in sediment, samples have been screened using the laboratory LOR.

PFOS and PFOA were detected above the LOR at some sediment sample locations. Concentrations of PFAS in sediment were below the commercial / industrial or open space human health soil guidance values.

### 9.4.3 Wodonga Creek

Wodonga Creek receives water from both Jack in the Box Creek and the Murray / Kiewa River. Wodonga Creek is the sole source of water for Wodonga (extracted by North East Water) and surrounding townships.

#### Sampling Plan

The sample locations are presented on Figure 16A. For further details Appendix D presents the sampling completed.

#### Surface Water and Sediment Results

Four co-located surface water and sediment samples were collected from within Wodonga Creek, with vertical variability assessed at two locations. The sample descriptions are included in Tables A and B, and analytical results are included in Tables J and K. The sampling locations are identified on Figure 16A.

There were no reported surface water PFAS exceedances of the human health water guidance values.

The PFAS exceedances of the ecological guidance values included:

- Concentrations of PFOS in samples SW436 at 1.0 m depth (0.0013 µg/L) and 1.5 m depth (0.0027 µg/L), and SW437 at 2.0 m depth (0.0006 µg/L) which exceeded the 99% species protection guidance value (0.00023 µg/L) for freshwater.

PFAS concentrations in the five sediment samples were below the laboratory LOR.

### 9.4.4 Land Adjoining South Bandiana

Land located adjacent to the western boundary of South Bandiana was formerly owned by the Department of Defence.
Sampling Plan
The sample locations are presented on Figures 15A for groundwater, and 16A for sediment and surface water. For further details Appendix D presents the sampling completed.

Groundwater Results
The monitoring well locations are identified on Figure 15A and analytical results are presented in Table M. There were no reported PFAS exceedances of the human health guidance values.

Sediment Results
The sample descriptions are included in Tables B, and analytical results are included in Table K. The sampling locations are identified on Figure 16A.

The concentrations of PFAS detected were below the interim indirect open space and indirect residential / parkland ecological soil guidance values, and below human health open space soil guidance values.

9.4.5  Land Adjoining North Bandiana
Land located immediately east of North Bandiana and north of East Bandiana is divided by an unnamed creek which flows through North Bandiana and receives water from the eastern portion of South Bandiana (via the stormwater ponds (wetlands) at the entrance to South Bandiana).

The land historically also contained a former STP which received wastewater from BMA.

Soil Results
The sample descriptions are included in Table E, and analytical results are included in Table L. Sample locations are identified on Figure 14B.

The creek is an open space land use and is zoned as Public Conservation and Resource Zone under the Wodonga Council Planning Scheme.

There were no reported PFAS exceedances of the open space human health guidance values or the interim direct open space or indirect residential / parkland ecological soil guidance values.

Groundwater Results
The analytical results are presented in Table M. The groundwater well location is not able to be identified on figures due to stakeholder privacy requirements.

Surface Water and Sediment Results
Surface water and sediment sampling descriptions are presented in Tables A and B. The sampling locations able to be identified are shown on Figure 16C and analytical results are presented in Tables J and K.

The PFAS concentrations in surface water were below the human health recreational water guidance values. Concentrations of PFOS+PFHxS at seven locations exceeded the adopted drinking water (0.07 μg/L) guidance values including, SW406 (0.115 μg/L), SW409 (0.115 μg/L), SW410 (0.0888 μg/L), SW411 (0.16 μg/L), SW412 (0.213 μg/L), SW462 (0.117 μg/L) and SW464 (0.155 μg/L).

There were no reported exceedances of the ecological guidance values for PFOA in surface water, however, PFOS exceedances were reported in the seven samples collected and analysed including:
Concentrations of PFOS within the unnamed creek ranged between 0.043 µg/L (SW408) and 0.114 µg/L (SW464) which exceeded the 99% (0.00023 µg/L) species protection guidance value for freshwater.

Concentrations of PFOS within the stormwater settling ponds in sample SW465 (0.0059 µg/L) and SW466 (0.0211 µg/L) exceeded the 99% (0.00023 µg/L) species protection guidance values for freshwater.

As the creek is open space, and accessible to recreational users and maintenance works, the reported sediment sample concentrations have been compared against the open space human health soil guidance values. As there are no ecological guidance values for PFAS in sediment, samples have been screened using the laboratory LOR.

PFAS was detected above the LOR at some sediment sample locations. There were no reported exceedances of the open space human health soil guidance values for PFAS in sediment.

9.4.6 Kiewa River including Middle Creek

The Kiewa River receives drainage from the eastern portion of South Bandiana, and North and East Bandiana. Samples collected from oxbow lakes are generally considered to be located on properties with a rural land use, while samples collected from within creek and river channels are conservation / open space land use areas.

Groundwater Results

Groundwater samples were collected from three monitoring wells installed along the Kiewa River (MW356, MW357 and MW358). The monitoring well locations are identified on Figure 15B and analytical results are present in Table M.

The PFAS exceedances of the human health guidance values included:

- Concentrations of PFOS+PFHxS in sample 0445_MW357 (0.111 µg/L) located near the confluence of the unnamed creek and the Kiewa River which exceeded the adopted drinking water guidance values (0.07 µg/L).
- The three groundwater wells located along the Kiewa River are considered to be immediately up-gradient of receiving surface water bodies. PFAS exceedances of the ecological guidance values were reported as follows:
  - Concentrations of PFOS in samples 0445_MW356 (0.0009 µg/L), 0445_MW357 (0.034 µg/L) and 0445_MW358 (0.0008 µg/L) which exceeded the 99% species protection guidance values (0.00023 µg/L) for freshwater.

Surface Water and Sediment Results

Twenty-nine co-located surface water and sediment samples were collected including:

- 15 samples from within the Kiewa River and its main tributary Middle Creek including one sample from the confluence of the unnamed creek and the Kiewa River; and
- 14 samples from oxbow lakes, dams and depositional zones on the floodplain.

The sampling locations are identified on Figure 16B and 16C and analytical results are present in Tables J and K.

The PFAS exceedances of adopted human health surface water guidance values are summarised below:

- Oxbow lakes / depositional zones on the floodplain (rural land use):
Concentrations of PFOS+PFHxS in samples SW395 (0.224 µg/L), SW401 (0.687 µg/L), SW403 (0.224 µg/L), SW405 (0.230 µg/L), SW411 (0.16 µg/L) and SW412 (0.213 µg/L) exceeded the adopted drinking water guidance values (0.07 µg/L).

Concentrations of PFOS+PFHxS in samples SW396 (1.91 µg/L), SW397 at 0.5 m (m bgl) (12.8 µg/L), 1.0 m depth (12.3 µg/L) and 1.3 m depth (12.7 µg/L), SW399 (1.06 µg/L) and SW400 (0.826 µg/L) exceeded the adopted drinking water guidance values (0.07 µg/L) and the adopted recreational water guidance values (0.7 µg/L).

Kiewa River channel and tributaries:

Concentrations of PFOS+PFHxS in sample SW462 (0.117 µg/L) located near the confluence of the unnamed creek and the Kiewa River which exceeded the adopted drinking water guidance values (0.07 µg/L).

The PFAS exceedances of adopted ecological surface water guidance values summarised below:

Oxbow lakes / depositional zones on the floodplain (rural land use):

Concentrations of PFOS in samples collected from oxbow lakes ranged from <0.0003 µg/L (SW446) located on the eastern side of the Kiewa River to 5.74 µg/L (SW397) located on the western side on the Kiewa River and immediately east of East Bandiana.

Concentrations of PFOS at eight sample locations exceeded the 99% species protection guidance values (0.00023 µg/L) for freshwater including the sample from SW442 (0.0003 µg/L) collected from the upstream oxbow lake.

Concentrations of PFOS at four sample locations exceeded the 95% (0.13 µg/L) and the 99% (0.00023 µg/L) species protection guidance values for freshwater. These sample locations were all directly east of East Bandiana and include SW396, SW399, SW400 and SW401.

Concentrations of PFOS from the three samples collected at SW397 at 0.5 m depth (5.74 µg/L), 1.0 m depth (5.38 µg/L) and 1.3 m depth (5.61 µg/L) exceeded the 90% (2 µg/L), 95% (0.13 µg/L) and the 99% (0.00023 µg/L) species protection guidance values for freshwater.

Kiewa River channel and tributaries:

Concentrations of PFOS in samples collected from within the channels of Middle Creek, the unnamed creek and Kiewa River ranged from <0.0003 µg/L to (SW414, SW416 and SW417) to 0.0617 µg/L (SW462) located near the confluence of the unnamed creek and the Kiewa River.

Concentrations of PFOS at twelve sample locations exceeded the 99% species protection guidance values (0.00023 µg/L) for freshwater including the upstream samples (SW389, SW390, SW391 and SW443). With the exception of SW462 (0.0617 µg/L), the concentrations detected were less than or equal to 0.001 µg/L.

Sediment assessment guidance values have not yet been provided for either human health or ecological receptors as there are currently no nationally accepted human health or ecological guidance values for PFAS in sediment. However, to assess potential risk to people who may encounter sediments, such as maintenance workers or those involved in recreational activities, the reported sediment sample concentrations have been compared against the open space human health soil guidance values. As there are no ecological guidance values for PFAS in sediment, samples have been screened using the laboratory LOR.
There were no reported exceedances of the open space human health soil guidance values for PFAS in sediment. PFOS and PFOA were detected above the LOR at some sediment sample locations inundated with water, primarily those sample locations from oxbow lakes or depositional zones on the Kiewa River floodplain.

**9.4.7 Murray River**

The Murray River receives water from the Kiewa River and provided an opportunity for the collection of background samples and samples near the confluence of the Kiewa River and the Murray River.

**Surface Water and Sediment Results**

Five co-located surface water and sediment samples were collected from within the Murray River. The sample descriptions are included in Tables A and B, and analytical results are included in Tables J and K. The sampling locations are identified on Figure 16B.

PFAS compounds were detected in three surface water samples collected including SW421, SW440 and SW441 all located upstream of the Kiewa River confluence.

There were no reported surface water PFAS exceedances of the human health guidance values.

The surface water PFAS exceedances of the ecological guidance values included:

- Concentrations of PFOS in samples 0445_SW421 (0.0026 µg/L), 0445_SW440 (0.0014 µg/L) and 0445_SW441 (0.0019 µg/L) which exceeded the 99% species protection guidance value (0.00023 µg/L) for freshwater.

PFAS concentrations in the five sediment samples were below the laboratory LOR.

**9.5 Point of Use Investigations**

Point of use sampling was completed at five of 212 properties which returned WUS (Section 7.2). This included one property within the Jack in the Box Creek catchment, and four properties within the Kiewa River catchment. Analytical results for the point of use sampling are included in Tables O to Q. It is noted that due to stakeholder privacy requirements the position of sampling locations are not identified.

The point of use investigation results are generally presented according to the respective drainage catchments, including:

- Jack in the Box Creek catchment.
- Kiewa River catchment.

**9.5.1 Jack in the Box Creek**

Point of use sampling was undertaken at one property within the Jack in the Box Creek catchment, located to the north-west of South Bandiana. The property is supplied by mains water. The property contains a drainage channel which potentially receives water from Jack in the Box Creek during high flow events and included fruit / vegetable gardens which were watered with mains water.

The following samples were proposed to be collected:

- Eight co-located sediment and surface water samples from a drainage channel – SW/SD453, SW/SD454, SW/SD455, SW/SD456, SW/SD457, SW/SD458, SW/SD459 and SW/SD46. It is noted that five locations were dry and as such surface water samples SW453, SW454, SW458, SW459 and SW460 could not be collected.

- One co-located sediment and surface water sample from a stormwater pit – SW/SD461. A sediment sample was not able to be collected as the pit was concrete lined.
Two surface soil samples from the upper edges of the drainage channel – SS331 and SS331.

Given the site use, it was considered appropriate to compare the analytical results to low density residential land use guidance values for soil and sediment. It was considered appropriate to compare the analytical results for surface water against both drinking water and recreational water guidance values.

**Soil Results**

The sample descriptions are included in Tables E, and analytical results are included in Tables P PFAS concentrations were below the laboratory LOR except for PFOS in both samples (Table P). Concentrations of PFOS were below the low density residential human health and interim indirect residential / parkland ecological guidance values.

**Surface Water and Sediment Results**

Four surface water samples were collected, including three from the drainage channel / overland flow path and one from a stormwater pit. It is noted that significant rainfall was experienced prior to and during the sampling, however, the overland flow path was not receiving flow from Jack in the Box Creek at the time of sampling. As such the surface water samples collected from the drainage channel are most appropriately described as rainwater puddles.

The sample descriptions are included in Tables A and B, and analytical results are included in Tables N and O.

PFAS compounds were detected in the four surface water samples collected (Table N). There were no reported PFAS exceedances of the human health guidance values. The reported PFAS exceedances of the ecological guidance values included:

- Concentrations of PFOS in samples 0445_SW455 (0.0384 µg/L), 0445_SW456 (0.0149 µg/L), 0445_SW457 (0.0646 µg/L) and 0445_SW461 (0.0184 µg/L) which exceeded the 99% species protection guidance values (0.00023 µg/L) for freshwater.

To assess potential risk to site occupants who may enter the drainage channel / overland flow path, as a conservative approach, the reported sediment sample concentrations were compared against the low density residential soil guidance values. Concentrations of PFAS were below the human health and interim indirect ecological soil guidance values for low density residential land use in the eight sediment samples analysed.

**9.5.2 Kiewa River Catchment**

Point of use sampling was undertaken at four properties within the Kiewa River catchment. This includes sampling from three properties to the south of East Bandiana (considered to be up-gradient of the main source areas) and one property on the eastern side of the Kiewa River (considered to be down- to cross-gradient).

The following samples were proposed to be collected:

- Three co-located surface water and sediment samples from dams located on properties to the south of East Bandiana – SW/SD450, SW/SD451 and SW/SD452.
- Four groundwater samples from bores located south of East Bandiana – OTH001, BH1, BH2 and BH3. One bore (OTH001) is used for agricultural water supply.
- Eleven samples from domestic water supply points from the property on the eastern side of the Kiewa River including:
  - Four samples from rainwater tanks (OTH008, OTH009, OTH010 and OTH016).
Four samples from garden taps supplied by a bore located on the property (OTH011, OTH012, OTH013 and OTH014).

Two samples from taps inside the main residence including one fed by bore water (OTH017) and one fed by rainwater (OTH018).

One sample from a leak at the water supply bore (OTH015). It is noted that direct access to the bore was not possible.

It was considered appropriate to compare the analytical results to low density residential land use guidance values for soil and sediment. It was considered appropriate to compare the analytical results for surface water against both drinking water and recreational water guidance values.

**Surface Water and Sediment Results - Dams**

Three co-located surface water and sediment samples were collected from dams used for watering fruit / vegetable gardens and stock watering (SW/SD450, SW/SD451 and SW/SD452). The sample descriptions are included in Tables A and B, and analytical results are included in Tables N and O.

There were no reported PFAS exceedances of the human health guidance values. The reported PFAS exceedances of the ecological guidance values for the surface water included:

- Concentrations of PFOS in samples 0445_SW450 (0.0018 µg/L), 0445_SW451 (0.0005 µg/L) and 0445_SW452 (0.0009 µg/L) which exceeded the 99% species protection guidance value (0.00023 µg/L) for freshwater.

PFAS concentrations in the three sediment samples 0445_SD450, 0445_SD451 and 0445_SD452 were below the laboratory LOR.

**Water – Tanks and Taps**

Eleven samples were collected from domestic water supply points from a property on the eastern side of the Kiewa River, on the periphery of the investigation area. Water on the property is both extracted from a shallow bore and rainwater is harvested for domestic use (including drinking), watering a fruit / vegetable garden and stock watering. The sample descriptions are included in Table A, and analytical results are included in Table R.

The PFAS concentrations in the 11 water samples were below human health drinking water and recreational guidance values.

**Groundwater - Bores**

Groundwater samples were collected from four bores up-gradient of East Bandiana, including one water supply bore (OTH001) which is understood to be used to water fruit / vegetable gardens and the property grounds.

The PFAS exceedances of the human health guidance values included:

- Concentrations of PFOS+PFHxS from BH3 (0.759 µg/L) exceeded the adopted drinking water and recreational water guidance values (0.07 µg/L). It is noted that this bore is not used for extractive purposes and no known extraction bores were identified in the vicinity of BH3 during the investigation through the WUS or a review of registered bores.
The PFAS exceedances of the ecological guidance values included:

- Concentrations of PFOS in samples 0445_OTH001 (0.0007 µg/L), BH1 (0.0007 µg/L), BH2 (0.0118 µg/L) and BH3 (0.0324 µg/L) which exceeded the 99% species protection guidance value (0.00023 µg/L) for freshwater.

10.0 CONCEPTUAL SITE MODEL

For a risk to a receptor to occur, a complete pathway must exist between the source of contamination and the potential receptor. Where the contaminant pathway is incomplete, there is no exposure and hence no risk via that pathway. A Source-Pathway-Receptor (SPR) linkage represents the possible scenarios whereby the source of PFAS, could present an unacceptable risk to human health or ecological receptors via a complete migration pathway and exposure route.

For the development of the Conceptual Site Model (CSM), the following routes have been considered where human health and/or ecological receptors are potentially exposed to PFAS:

- **Ingestion**
  - Human health - this includes ingestion by drinking potentially impacted water, or eating potentially impacted biota including home grown, agriculturally produced or caught foods, such as fruit and vegetables, livestock (cattle and chickens), game (fish or deer) and eggs. Furthermore, ingestion can also occur through incidental ingestion of impacted soil, sediment or water during either residential, recreational or occupational activities such as gardening, playing sports or undertaking grounds maintenance.
  - Ecological – this includes terrestrial and aquatic fauna species also being potentially exposed via the direct or incidental consumption of potentially impacted soil, sediment or water and the consumption of potentially impacted biota. In addition, higher trophic level predatory species are also potentially exposed to greater PFAS concentrations due to the tendency for PFAS compounds to bioaccumulate and biomagnify within ecosystems.

- **Inhalation**
  - Human health (only) – due to the low volatility of PFOS, PFOA and PFHxS, the inhalation of PFAS vapours was excluded by the NSW OEH (2017) in the derivation of the adopted soil screening guidance values. Consistent with NSW OEH, the inhalation of vapour is considered an incomplete exposure pathway, and the only inhalation pathway exposure route is via the inhalation of dust.

- **Contact**
  - Human health – in the derivation of the adopted soil screening guidance values, the NSW OEH (2017) noted that the dermal uptake of PFAS was assumed to be negligible and was omitted from the calculations. As such, while the exposed route is potentially complete dermal contact with PFAS impacted soil, sediment or water is not considered to represent a significant risk to human receptors. This is further considered in the evaluation of the CSM.
  - Ecological – for terrestrial and aquatic fauna species contact with PFAS impacted soils, sediment and/or water may result in potential exposure. For terrestrial and aquatic flora species, contact would be considered the primary exposure route.

Based on the historic site activities and potential chemicals of interest (identified as potential sources), the potential migration pathway and exposure routes which may exist for impacted soil, sediment, surface water and groundwater within the investigation area have been considered. Consultation and communication with
government agencies, community residential, business stakeholders, on-base personnel and Bandiana Primary School, as well as distribution of a WUS, have provided insight to the potential receptors and activities undertaken within the investigation area. The CSM is presented in a graphical cross section on Figure 17.

### 10.1 Jack in the Box Creek Catchment

#### 10.1.1 Source Areas

The Jack in the Box Creek catchment is situated in the western portion of South Bandiana. Based on the groundwater elevation data and surface water drainage channels, the Jack in the Box Creek catchment receives:

- Groundwater and surface water drainage from Source Areas 1 to 4 (located within the Close Training Area), 6 and 7.
- Groundwater from Source Area 5.
- Surface water from the western portions of Source Area 5.

It is noted that groundwater from Source Areas 8 and 9 may also contribute to Jack in the Box Creek, however, the location of the groundwater divide is somewhat uncertain due to the absence of groundwater data within the eastern portion of South Bandiana.

Based on the source area assessments undertaken, it is considered that Source Area 3 (Section 9.1.3), Source Area 4 (Section 9.1.4) and Source Area 8 (Section 9.1.8) are not PFAS impacted.

#### 10.1.2 Nature and Extent of Contamination

**Soil**

Samples collected from within the source areas contributing to the Jack in the Box Creek catchment, from general coverage areas and off-base along the creek are mostly within open space or commercial / industrial land use areas. PFAS was detected in on-base soil samples analysed, with higher concentrations of PFAS generally identified within and adjacent to source areas compared to those samples collected from on-base general coverage areas including along the base boundaries. PFOS was the dominant PFAS compound detected, with concentrations of PFOA, PFHxS, perfluorohexanoic acid (PFHxA), perfluoro-n-pentanoic acid (PFPeA), perfluorohexanesulfonic acid (PFHpS), perfluoropentansulfonate (PFPeS) and perfluorobutanesulfonic acid (PFBS) consistently detected at significantly lower concentrations.

Concentrations of PFAS generally decreased at depth within the soil profile for the majority of source areas. However, in Source Area 7, there was no clear trend between PFAS concentrations and depth. PFAS concentrations at many borehole and monitoring well locations within Source Area 7 were similar to surface concentrations or increased with depth. It is noted that soil profiles within Source Area 7 where PFAS concentrations similar or greater than surface concentrations were observed at depth generally appear to be related to locations where fill material was observed and analysed. In general, concentrations of PFAS in Source Area 7 appeared to be lower in fill material within the upper soil profile, in comparison to the natural underlying sandy clay or clay materials. Concentrations of PFAS generally decreased with depth in source areas where fill material was generally not observed (for example, Source Area 1 and 2 within the Close Training Area). The drilling locations advanced in these source areas had an upper soil profile which generally consisted of fine grained silts and clays.

The maximum concentration of PFOS+PFHxS detected within the on-base Jack in the Box Creek catchment was 1.97 mg/kg within Source Area 7 (Old Fire Station, Building 421). The concentrations of PFOS+PFHxS detected were below the adopted human health guidance values applicable to the land use of the area, with the exception of the surface samples collected at MW307 (1.04 mg/kg) in Source Area 1 (Petroleum Platoon –

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*GOLDER*
Former Fire Training Area) and MW317 (1.23 mg/kg) in Source Area 2 (Base Fire Services – Former Fire Training Ground) in the Close Training Area, which exceeded the human health open space guidance values (1.0 mg/kg). It is noted that while Source Area 7 is within a commercial / industrial land use zone, it is located adjacent to an on-base high density residential area.

Exceedances of the interim direct open space (1 mg/kg) and indirect residential / parkland (0.01 mg/kg) soil ecological guidance values for PFOS were noted within the Close Training Area (e.g. Source Area 1 and 2). Exceedances of the interim indirect commercial / industrial (0.14 mg/kg) soil ecological guidance values for PFOS were also noted in Source Area 6 (Current Fire Training Area) and Source Area 7 (Old Fire Station, Building 421). As noted above, while Source Area 7 is within a commercial / industrial land use zone, it is located adjacent to an on-base residential area.

The maximum off-base PFOS+PFHxS concentration detected was 0.0104 mg/kg from sample SS325 located immediately prior to where the creek discharges to surface from pipes, and within an overland flow path which is generally open space / parkland land use. Off-base PFOS concentrations in soil were below the interim direct open space guidance value (1 mg/kg) however exceeded the interim indirect residential / parkland ecological guidance value (0.01 mg/kg) in one sample (SS325).

The concentrations of PFOA detected were below human health guidance values, with a maximum concentration of 0.034 mg/kg reported within Source Area 7 (Old Fire Station, Building 421). Off-base soil concentrations of PFOA were below the laboratory LOR.

Concentrations of 6:2 FtS were detected at on-base locations MW307 (Source Area 1 – Petroleum Platoon Former Fire Training Ground), BH337 (Source Area 6 – Current Fire Training Area), and BH301 and MW322 (Source Area 7 – Old Fire Station, Building 421). The concentrations of 6:2 FtS ranged between 0.0005 mg/kg (BH337_0.3) and 0.0216 mg/kg (MW307_2.0).

**Groundwater**

The groundwater wells installed and sampled within the Jack in the Box Creek catchment were primarily installed within the Shepparton Colluvium with a small number of wells installed in the OMC including the background groundwater well (MW362) and two wells installed in the Shepparton Fluvium downstream along Jack in the Box Creek (MW360 and MW361). Groundwater flow through the catchment appears to be dominated by Bears Hill and Huon Hill. Groundwater generally flows to the north to north-west from the base of Bears Hill through the Close Training Area and flows generally towards Jack in the Box Creek, and to the south from the base of Huon Hill prior to flowing west and then assimilating with the overall north-westerly flow direction towards Jack in the Box Creek. Groundwater flow is ultimately inferred to be discharging into Wodonga Creek. However, the surface water and groundwater interaction at Wodonga Creek is likely to be complex and has not been investigated in detail.

Low concentrations of PFAS were detected in 16 on-base groundwater samples from within the Jack in the Box Creek catchment and within each of the seven off-base groundwater wells. However, it is noted that off-base samples were analysed for trace PFAS which allowed for PFAS to be detected at much lower levels in comparison to on-base samples. PFOS was generally the dominant PFAS compound detected in groundwater, with concentrations of PFHxS consistently detected at significantly lower concentrations.

PFOA was detected in two on-base samples and three off-base samples, and 6:2 FtS was detected in one off-base sample. PFHxA, PFHpA, PFPeA, PFHxS, PFPeS and PFBS were detected in a limited number of on-base and off-base groundwater samples, as well as perfluorobutanoic acid (PFBA) which was detected in one off-base sample.
The two groundwater wells installed deeper within the Shepparton Colluvium (MW306 and MW328) both reported concentrations less than the laboratory LOR. Particularly for MW306 located in Source Area 1, where the up-gradient and down-gradient shallow wells reported detections of PFAS, this indicates that contamination is currently unlikely to be extending vertically through the water column.

The highest on-base concentrations of PFAS in groundwater were generally detected in close proximity to source areas, however, concentrations of PFAS in boundary wells, MW304 and MW312 located along the northern boundary, were of a similar magnitude to concentrations of PFAS in some source areas. Concentrations of PFAS in the background well (MW362, located approximately 100 m east of Source Area 4) were below the laboratory LOR.

Concentrations of PFOS+PFHxS were detected above human health drinking water guidance values in the following groundwater wells:

- MW307 and MW311 both installed within the Shepparton Colluvium and located in Source Area 1 (Petroleum Platoon Former Fire Training Ground).
- MW319 and MW321 both installed within the Shepparton Colluvium and located in Source Area 7 (Old Fire Station, Building 421). The PFOS+PFHxS concentrations detected in MW321 also exceeded recreational water guidance values.
- MW312 installed within the Shepparton Colluvium and located along the northern boundary of South Bandiana within the Close Training Area.
- BH111 located in Source Area 9 (POL) which is on or near the groundwater divide. It is noted that BH111 is installed in perched water identified within the Shepparton Colluvium and is nested with BH157 which did not report concentrations of PFAS above the laboratory LOR. The PFOS+PFHxS concentrations detected in BH111 also exceeded recreational water guidance values.

As discussed in Section 6.6.7, the groundwater classification based on the Vic Groundwater SEPP (1997) for the Jack in the Box Creek catchment is Segment A1 / A2 to which potable water is designated a protected beneficial use. However, given the slow recharge observed during well development and sampling, and the low hydraulic conductivity, groundwater extraction is unlikely to be feasible. Furthermore, the TDS measured in the majority of wells within the on-base Jack in the Box Creek catchment indicate that groundwater is not suitable for potable uses.

The off-base groundwater PFOS+PFHxS concentrations generally decreased with distance from the base for those wells screened within the stiff clays of the Shepparton Colluvium. However, groundwater concentrations of PFOS+PFHxS were significantly higher, and above drinking water guidance values (and therefore precluding some protected beneficial uses e.g. domestic and stock watering), for the two downstream off-base groundwater wells (MW360 and MW361) installed in the sandier Shepparton Fluvium. These two wells are located approximately 1.2 km and 2.7 km, respectively from the nearest on-base source area (Source Area 1). The fluctuation in concentrations of PFAS down the flow path, suggests either alternative sources are contributing to the groundwater in the vicinity of MW360 and MW361, or the groundwater is receiving PFAS contributions from the surface water (or a combination of the two scenarios is occurring). Potential alternative sources including the Wodonga Fire Station and Country Fire Authority were identified within the Jack in the Box Creek catchment, which may be contributing to PFAS concentrations in groundwater. The following is noted in relation to theses potential alternative sources:

- MW360 is located south-east (inferred up-gradient) of the Wodonga Fire Station and Country Fire Authority, therefore, given the up-gradient location it is unlikely that these potential alternative sources are contributing to PFAS in groundwater at this location.
MW361 is located east north-east (inferred cross- to down-gradient) of the Wodonga Fire Station and Country Fire Authority, and as such these potential alternative sources may be contributing to PFAS in groundwater at this location.

The Wodonga Fire Station and Country Fire Authority are located approximately 1.3 km to the west of Jack in the Box Creek and 0.6 km to the east of House Creek with the topography generally sloping towards the north to Wodonga Creek. Based on the topography and proximity of House Creek in comparison to Jack in the Box Creek, the inferred groundwater flow direction in the vicinity of the Fire Station and Fire Authority is towards the north. Therefore, it is considered unlikely that potential groundwater impacts resulting from the Wodonga Fire Station or Country Fire Authority were identified in MW361 (or MW360).

Surface water runoff from the Wodonga Fire Station and Country Fire Authority is likely to enter the municipal stormwater pipe system. However, based on the information able to be obtained through Dial Before You Dig searches, the discharge point of surface water runoff is unknown.

It is noted that MW360 and MW361 are both located in close proximity to commercial and industrial properties. Therefore, there is the potential for other alternative sources to exist outside of the BMA and Wodonga Fire Station and Country Fire Authority.

**Surface Water**

A total of 39 surface water sample locations were proposed on-base within the Jack in the Box Creek catchment, however, only ten samples were able to be collected as the drainage channels proposed for sampling were generally observed to be dry during the investigation. Surface water samples were collected from 13 of the 14 proposed off-base locations along Jack in the Box Creek (including an additional sample from ponded water observed along the overland flow path (SW449) and from a pond which was identified to contain yabbies located north-west of the base boundary (SW463). Two sampling events, pre- and post-rain event, were undertaken at one location (SW424). In addition, eight surface water samples from four locations within Wodonga Creek and four point of use surface water samples were collected. The Wodonga Creek samples were collected during periods of high flow with river levels recorded between 1.3 and 2.9 m. While there are no gauging stations along Wodonga Creek, it is noted that water levels in the Kiewa River during surface water sampling were in the order of 2.5 m\(^2\), in comparison to average low water conditions of 1.0 to 1.5 m depth. Water levels at the nearby Murray River gauging stations also appear to exhibit a similar trend with generally higher water levels between the months of August and October (Section 6.4.2).

PFAS was detected in the on-base, off-base and point of use surface water samples collected and analysed. The concentrations of PFAS detected within the on-base samples were relatively uniform (PFOS ranging from 0.024 to 3.98 µg/L) across the on-base Jack in the Box Creek catchment area. However, one sample (SW336) collected from the sediment pond in Source Area 6 (Current Fire Training Area) reported concentrations of 48 µg/L of PFOS.

Concentrations of PFAS in samples collected from along drainage lines in general coverage areas (i.e. not directly within a source area) were commonly of a similar magnitude to samples collected from within a source area. This indicates that there is wide-spread PFAS impacted surface water across the on-base Jack in the Box Creek catchment area and along Jack in the Box Creek off-base. It is noted that concentrations of PFAS were greater in the sample collected pre-rain event at SW424 where water was stagnant, compared to the post-rain event sample where water was flowing suggesting some dilution had occurred with the rain event.

\(^{12}\) Relative to the river bed at the sampling location.
PFOS was the dominant PFAS compound detected, with concentrations of PFOA, PFHxS, PFHpA, perfluorodecanoate (PFDA), PFPeA, perfluorononanoate (PFNA), PFHpS, PFPeS and PFBS consistently detected at significantly lower concentrations.

Concentrations of PFOS+PFHxS exceeded human health drinking water guidance values in nine of the ten on-base samples, with seven of these samples also exceeding recreational water guidance values. The off-base PFOS+PFHxS concentrations were highest closest to the base and generally decreased in a downstream direction. The two samples collected immediately downstream of the base (SW424 and SW463) both exceeded human health drinking water and recreational guidance values. Sample SW424 was collected from a marshy area to the east of Victoria Cross Parade and SW463 was collected from a pond within a bushland area to the north-west of South Bandiana. Both areas are accessible to the public and zoned for open space land use, and the pond was observed to contain yabbies and yabby traps. Concentrations of PFAS exceeding the drinking water guidance values were identified for the majority of Jack in the Box Creek, except for the samples collected approximately 450 m upstream of the Wodonga Creek confluence.

Detectable concentrations of PFAS were reported in the two samples collected from the lower 450 m of Jack in the Box Creek (SW433 and SW434).

The eight surface water samples collected from four locations within Wodonga Creek, including the location near the municipal water off-take were below the adopted human health drinking water guidance values for PFOS+PFHxS and PFOA. PFAS concentrations in the samples collected from upstream (west) of the off-take and the Jack in the Box Creek primary confluence (SW438) and from downstream of the primary confluence (SW435) were below laboratory LOR. Low concentrations of PFOS were detected in samples collected from the Jack in the Box Creek confluence (SW436) and immediately downstream of the off-take (SW437). Other than PFOS, no other PFAS compounds were detected in these samples. It is noted that while the concentrations of PFAS detected were below the adopted human health guidance values, the samples were collected during periods of high flow.

Concentrations of PFOS were above the adopted ecological screening guidance values for on-base samples and off-base samples collected. Although it is noted that many of these exceedances were of the conservative 99% level of protection screening guidance value, which have been applied in accordance with the Vic Surface Waters SEPP (2003) and to allow for the potential for bioaccumulation. In particular, it is noted that Jack in the Box Creek is considered to be a highly modified system, and as such the 95% level of protection screening guidance value is considered to be more appropriate. Only two off-base sample locations (SW424 and SW463) in the upper Jack in the Creek catchment exceeded the 95% screening guidance values for PFOS.

**Sediment**

Sediment samples were collected from 36 of the 39 proposed locations within the on-base Jack in the Box Creek catchment, with three sediment samples from lined ponds not able to be collected. Sediment samples were collected from 11 of the 13 proposed off-base locations along Jack in the Box Creek (including an additional sample from a pond which was identified to contain yabbies located north-west of the base boundary [SW463]). Two sampling events, pre- and post-rain event, were undertaken at one location (SW424). In addition, eight sediment samples from four locations within Wodonga Creek and eight point of use sediment samples were collected along the Jack in the Box Creek overland flow path.

The on-base sediment samples collected from ponds or dams were generally described as silts or clays, while the soil conditions along drainage lines was considerably more variable. Off-base samples were also varied, however, it was generally observed that sample locations near areas of higher flow, such as SD427 where Jack in the Box Creek is diverted into pipes, and SD433 and SD434 near the Wodonga Creek confluence,
generally exhibited coarser grained sediments. Similarly, the sediments within Wodonga Creek were generally coarser, with the exception of the sediment core at SD437 which predominantly contained silt and clay.

Concentrations of PFAS were detected in on-base sediment samples and off-base samples along Jack in the Box Creek with the exception of SD339 located in Source Area 5 (Petroleum Platoon – Fuel Handling Facility), and SD430, SD432, SD433 and SD434 located along the downstream reaches of Jack in the Box Creek. Concentrations of PFAS in on-base sediment samples were generally higher in close proximity to source areas, however, samples collected from general coverage areas across the base all reported low concentrations of PFAS. Similar to surface water, concentrations of PFAS in sediment generally decreased in a downstream direction. PFAS was not detected in the sediment samples collected from Wodonga Creek, albeit the sediments within Wodonga Creek were generally described as sands and gravel with moderate TOC which may present less opportunity for the adsorption of PFAS compounds within the sediments. It is noted that concentrations of PFAS in sediment were of a similar magnitude in the samples collected pre- and post-rain event from SW424. This is contrary to surface water concentrations at that location which were considerably higher during the pre-rain sampling.

Similar to surface water, PFOS was the dominant PFAS compound detected in on-base sediment samples, with concentrations of perfluorodecanesulfonate (PFDS), PFOA, PFHxS, PFHxA, perfluoroheptanoic acid (PFHpA), PFDA, PFPeA, PFNA, perfluorododecanoic acid (PFDoDA), perfluoroundecanoic acid (PFUnDA), PFHpS, PFPeS and PFBS consistently detected at significantly lower concentrations. Two on-base sediment samples reported detections of 6:2 FtS. PFOS was also the dominant PFAS compound detected in off-base sediment samples along Jack in the Box Creek, however, the range of other PFAS compounds detected was limited to PFOA in one sample, PFHxS in four samples and PFHxA in one sample.

The concentrations of PFOS+PFHxS detected within Source Area 2 (SD302, SD303 and SD304) exceeded the human health open space guidance values. The maximum concentration of PFOS+PFHxS in sediment detected within the on-base Jack in the Box Creek catchment was 13.3 mg/kg within Source Area 2 (SD304) and the maximum off-base concentration detected was 0.016 mg/kg from sample SD424 located immediately off-base along the upper reaches of Jack in the Box Creek. The remaining on-base and off-base samples reported PFAS concentrations below the adopted human health open space or commercial / industrial guidance values.

The on-base sediment samples were primarily collected from drainage channels which were frequently observed to be dry during the investigation, however, the drainage line running along the northern perimeter of the Close Training Area was observed to be wet. Samples from drainage lines frequently observed to be dry during the investigation were screened against interim direct and indirect soil guidance values for ecological purposes, and samples from areas frequently observed to be wet or inundated were screened against the LOR.

Sediment locations frequently observed to be dry reported exceedances of the interim direct open space (1 mg/kg) and indirect residential / parkland (0.01 mg/kg) soil ecological guidance values for PFOS in the on-base Jack in the Box Creek catchment. Both PFOS and PFOA were detected above the LOR at locations with consistent water coverage in the on-base and off-base Jack in the Box Creek catchment.

10.1.2.1 Pathways

Based on the site setting, there is potential for the PFAS contamination to be transported via either soil / sediment, surface water, groundwater or biota. The results of the investigations indicated the key pathway for the migration of PFAS impacts away from the source areas identified on South Bandiana within the Jack in the Box Creek catchment is via surface water (i.e. via water travelling through the creeks etc.).
However, within the off-base Jack in the Box Creek catchment, there is some uncertainty around the increase in PFAS concentrations in the groundwater down the flow path. Groundwater concentrations of PFOS+PFHxS were significantly higher, and above drinking water guidance values, for the two downstream off-base groundwater wells (MW360 and MW361) installed in the sandier Shepparton Fluvium. These are positioned approximately 1.2 km and 2.7 km respectively from the nearest on-base source area (Source Area 1).

The increase in concentrations of PFAS down the flow path may be due to several factors, including:

- Contribution of alternative off-base sources of PFAS.
- Increased infiltration of surface water through the sandier Shepparton Fluvium within the lower catchment compared to the clay soils associated with the Shepparton Colluvium of the upper catchment.
- Greater contribution from residual sediment impacts, where the increased infiltration of surface water, especially within the deeper sediment profile, may also be increasing the leaching of PFAS impacts from the sediments into the groundwater.

Based on the depth to groundwater within the upper portions of the Jack in the Box Creek, direct groundwater and surface water interaction are unlikely to be occurring. However, there is a likely interaction between surface water and groundwater near the Jack in the Box Creek and Wodonga Creek confluence. As such there is the potential that PFAS concentrations identified above the drinking water guidance values in the lower Jack in the Box Creek catchment groundwater are contributing to the PFAS concentrations identified within Wodonga Creek. The groundwater may also be interacting with surface water within the oxbow lakes identified within the small parcel of agricultural land on the southern bank of Wodonga Creek. Given the reported low PFAS impacts in soils in off-base soils and sediments, wind and atmospheric dispersion of PFAS impacted soils and sediments is not significant.

The nature of the surface water and groundwater interaction is likely to be variable based on the seasonal water levels, which are not fully understood.

### 10.1.3 Receptor Linkages

The SPR linkages for the Jack in the Box Creek catchment have been separated into on-base and off-base areas, and are further discussed and represented in the flow charts below (Plate 9 and Plate 10).

#### On-base Human Receptors

Based on the primary sources and the extent and nature of the secondary sources of PFAS contamination across the base, the following potential SPR linkages to on-base human receptors have been identified:

- **On-base residents** who live on the base and are potentially exposed via:
  - Incidental ingestion of soil and / or water on the base and eating potentially impacted biota grown or caught on the base.
  - Inhalation of dust.

PFAS source areas and PFAS impacted soils / sediments were not identified within (or within close proximity) of the on-base residential areas.

PFAS in soil concentrations in Source Area 7 (Old Fire Station, Building 421), which is located adjacent to an on-base residential area, were greater than human health screening guidance values for low...
density residential land uses (NEPM HIL A\textsuperscript{13}), however, were below the medium / high density residential criteria (NEPM HIL B\textsuperscript{14}).

The accommodation adjacent to Source Area 7 (Old Fire Station, Building 421), was observed to be medium density style accommodation with units and townhouses. And based on information provided by Defence, the accommodation is also used for relatively short periods, with living-in periods ranging up to a maximum posting cycle of 3 years, however also including short periods of 2 – 3 weeks. Therefore, the PFAS impacted soils identified within Source Area 7 do not present a significant risk to users of the adjacent accommodation area.

Based on the observations and information provided during the site investigations, the on-base residential areas, including those in close proximity to Source Area 7 do not include the production or consumption of home grown foods, such as fruit and vegetables, or livestock (chickens / eggs) and the hunting or catching of game (fish or deer) are not permitted on the base. Therefore, the potential exposure to on-base residents through the consumption of foods produced on the base is considered an incomplete exposure route. Management actions may need to be considered to ensure these restrictions continue to be enforced into the future.

A portion of South Bandiana along the base of Bears Hill and a portion of North Bandiana to the south-east of the unnamed creek are leased to a licenced grazier for sheep grazing. Sheep on South Bandiana have access to a dam located in the south-eastern portion of the grazing area which is fed by surface water runoff from Bears Hill – up gradient of the identified Source Areas, and a municipal-supply fed water trough. Sheep on North Bandiana are watered from a municipal-supply fed water trough. It is understood that sheep on North Bandiana do not have access to the unnamed creek. Due to the tendency for PFAS compounds to accumulate within biota, the level of risk associated with this potentially complete pathway will be the subject of a Human Health Risk Assessment.

PFAS concentrations in surface water exceeded the drinking water and recreational water guidance values in samples collected from both within the source areas and along drainage lines within the on-base Jack in the Box Creek catchment. Based on the information provided by Defence, surface water on the base is not used for recreational activities such as swimming, and children do not live on the base. As such the incidental ingestion of surface water is considered unlikely, and the PFAS concentrations in the surface water are not considered to present a risk to on-base residents or sensitive receptors as the exposure link is considered incomplete. Management actions may need to be considered to ensure this exposure is continued to be minimised.

Low concentrations of PFAS in groundwater were detected, with samples from five locations exceeding human health drinking water and / or recreational water guidance values. The groundwater has conservatively been classified as Segment A1 / A2, with potable water considered the most sensitive protected beneficial use. However, on-base extraction of groundwater is not occurring, and future on-base groundwater extraction is considered unlikely given the low hydraulic conductivity and the availability of mains water. Furthermore, the TDS of the groundwater within the majority of the on-base areas renders it unsuitable for drinking. Therefore, the potential exposure through the incidental ingestion of extracted groundwater on the site is considered an incomplete exposure route for residents. Management actions may need to be considered to restrict the future extraction of groundwater from the site.

\textsuperscript{13} NEPM Health Investigation Level - A Residential with garden and / accessible soil - assumptions with home-grown produce providing up to 10\% of fruit and vegetable intake (no poultry), also includes children’s day care centres, preschools and primary schools.

\textsuperscript{14} NEPM Health Investigation Level B Residential with minimal opportunity for soil access - assumptions with no use for home-grown produce and poultry and includes dwellings with fully and permanent paved yard space such as high rise – buildings and flats.
On-base workers, army personnel and site visitors who work or visit the base and are potentially exposed via:

- Incidental ingestion of soil and / or water on the base.
- Inhalation of dust.

The majority of the reported soil and sediment PFAS concentrations were below human health open space and commercial / industrial screening guidance values, and therefore do not present a risk.

The soil and sediment PFAS concentrations in Source Areas 1 and 2, which is in the Close Training Area where field training activities occur, exceeded the adopted human health open space soil screening guidance values, however were below the adopted human health commercial / industrial soil screening guidance values.

Based on information provided by Defence, field training activities are undertaken within the CTA twice a year, with the longer training course being the two week long Basic Soldier Training Course. The training mostly involves personnel walking across the Source Areas for ‘patrolling purposes’, (i.e. walking), wearing complete uniforms, body armour and packs. It was noted during review of the Defence activity in this area, that the training activities no longer involve significant soil disruption (i.e. no digging, or earthworks etc.), as they have installed lined concrete pits. However, the training does involve the camping / sleeping on the ground for the duration of the course, and may involve being close to the soil during selected activities (such as when leopard crawling). A trainee, would typically undertake the training once, during an 18-month rotation.

Based on the use of the area (i.e. no digging), the PFAS concentrations being below the commercial / industrial land use screening values, and the limited duration of the training activities - the risks associated with the identified PFAS impacts in the soil are not considered to present a risk.

Surface water exceeded adopted drinking water and recreational water screening guidance values in samples collected from both within the source areas and along drainage lines. While unlikely to present a significant risk, there is a potential exposure may occur if people accidently (or routinely) swallow the impacted surface water.

Based on information provided by Defence, surface water is not used for recreational activities. However, select training activities may include exposure to surface water:

- The abovementioned Basic Soldier Training Course, where a trainee could be exposed to surface water if there is inclement weather during the course; and
- Petroleum Operations training, undertaken within Source Area 5, where training involves repeatedly filling and emptying bladders and other storage devices with surface water (in lieu of petroleum) from a pond.

Surface water exposure may also happen when people are involved in maintenance activities on the BMA (such as clearing blocked drains). As such, while unlikely to present a significant risk, it is important to ensure appropriate health and safety controls are implemented when people are either involved in maintenance activities, or involved in training which use and/ or involve the exposure to surface water.

Perched groundwater was identified at approximately 3 m bgl within Source Area 9, with PFAS concentrations exceeding the recreational groundwater guidance values. As the groundwater in this area is shallow, there is potential for workers to be exposed if they are involved in construction or maintenance activities which encounter groundwater. Therefore, it is important to ensure appropriate health and safety controls for such activities. The depth to groundwater across the remainder of the
catchment exceeded 15 m bgl, and therefore workers involved in future excavation activities are unlikely to be exposed.

**On-base Ecological Receptors**

Based on the primary sources and the extent and nature of the secondary sources of PFAS contamination, the following potential SPR linkages to on-base ecological receptors have been identified:

- **Terrestrial or aquatic ecosystems** including flora and / or fauna which may be exposed to PFAS impacts on the base via:
  - Direct contact with and / or uptake of contaminants from soil, sediment or surface water.
  - Ingestion by fauna including eating impacted biota (including incidental ingestion of soil / sediment adhering to plants / grass) and drinking impacted surface water.
  - Ingestion by fauna of greater PFAS concentrations by higher trophic level predatory species due to the tendency for PFAS compounds to bioaccumulate and biomagnify within ecosystems.

Concentrations of PFAS were above the adopted ecological screening guidance values for soil, sediment, and surface water in the on-base Jack in the Box Creek catchment. The level of risk associated with the exceedances of the adopted ecological screening values will be the subject of an Ecological Risk Assessment.

**Off-base Human Receptors**

Based on the extent and nature of the secondary sources of PFAS contamination within the catchment, the following potential SPR linkages to off-base human receptors have been identified:

- **Off-base sensitive receptors** including people who either live, or attend schools or childcare facilities within the portions of the Jack in the Box Creek catchment downstream of the base and are potentially exposed via:
  - Drinking potentially impacted water.
  - Incidental ingestion of potentially impacted soil, sediment, surface water or groundwater.
  - Inhalation of potentially impacted dust.
  - Eating potentially impacted biota grown or caught within the catchment area, including home grown or agriculturally produced foods, such as fruit and vegetables and livestock (beef).

PFAS concentrations in off-base soil and sediment samples from within the Jack in the Box Creek catchment were below the adopted human health soil screening guidance values. Therefore, the incidental ingestion of potentially impacted soils and sediments and the inhalation of potentially impacted dust are not considered a risk.

The surface water flows exiting the base generally passed through commercial / industrial or open space land use zones, however a portion of the creek passed near sensitive land use areas where sensitive receptors could be exposed. The PFAS concentrations in surface water were highest closest to the base with two samples collected immediately downstream of the base in open space land use areas. These two samples exceeded both human health drinking water and recreational guidance values, whilst the remaining samples collected along Jack in the Box Creek exceeded only the drinking water guidance values. The extraction of surface water from Jack in the Box Creek for domestic or stock water purposes, is considered an incomplete pathway, based on the following:

- Goulburn-Murray Water indicated there is no licenced off-take from Jack in the Box Creek;
- the upper portion passes through open space and industrial land use areas;
the central portion is culverted underground, with generally overlying open space land use; and the lower portion passes through industrial areas where extraction would not occur.

As such the incidental ingestion of surface water, along the majority of the Jack in the Box Creek (including the areas which passed near sensitive receptors) and within Wodonga Creek is not considered a risk. The level of risk in the areas close to the base where there are exceedances of the Tier 1 screening values will be the subject of a Human Health Risk Assessment. The surface water samples collected from Jack in the Box Creek immediately prior to the Wodonga Creek confluence, and those samples collected from within Wodonga Creek from which municipal supply water is extracted reported PFAS concentrations below adopted drinking water screening guidance values. As such, based on the conditions assessed, it is safe to continue to drink the municipal water supply. The investigation understands from North East Water that an ongoing PFAS sampling program being conducted by North East Water involving the analysis of more than 60 samples (of both source and treated water) including during low-flow periods consistently reported levels of PFAS well below drinking water screening guidance values.

Additionally, based on outcomes of other studies conducted in Australia, concentrations of PFAS in water equivalent to the drinking water guidance values were considered safe to use for garden, poultry and stock watering. The Human Health Risk Assessment provides the mechanism of validating these findings considering the site-specific data collected.

The groundwater within the upper Jack in the Box Creek catchment is classified as Segment B, with primary contact (recreation) considered the most sensitive protected beneficial use. While groundwater within the lower Jack in the Box Creek catchment classified as Segment A1 or A2, where potable water is a protected beneficial use. The PFAS concentrations in groundwater within upper catchment, i.e. within the stiff clays of the Shepparton Colluvium closer to the base were below the adopted drinking water screening guidance values. However, concentrations of PFAS in groundwater were significantly higher, and above drinking water guidance values, for the two groundwater wells installed in the lower Jack in the Box Creek catchment within the sandier Shepparton Fluvium.

Due to the availability of mains water, and based on the results of the WUS and the search of the registered groundwater bore database, the widespread extraction of groundwater is not occurring within the catchment. Six registered domestic / stock bores were identified within the catchment, however the use of these bores was unable to be confirmed. While not confirmed as being realised, the PFAS concentrations identified in the lower catchment preclude the use of groundwater water as potable water. Overall, and given the unconfirmed use of groundwater as drinking water and the availability of mains water throughout the catchment, further assessment through the Human Health Risk Assessment is currently not proposed.

Due to the tendency for PFAS compounds to accumulate within biota, there is a potentially complete exposure pathway between the PFAS derived from the site, and the food people are consuming from within the catchment. The level of risk associated with this potentially complete pathway will be the subject of a Human Health Risk Assessment.

Recreational users including people using public open recreational spaces within the portions of the Jack in the Box Creek catchment downstream of the base and are potentially exposed via:

- Incidental ingestion of potentially impacted soil, sediment, surface water or groundwater.
- Inhalation of potentially impacted dust.
- Eating potentially impacted biota caught within the catchment area, including recreationally caught fish and yabbies.
Soil and sediment concentrations were below human health open space screening guidance values. Therefore, the incidental ingestion of potentially impacted soils and sediments and the inhalation of potentially impacted dust are not considered a risk.

PFAS concentrations in surface water were highest closest to the base with two samples collected immediately downstream of the base exceeding both human health drinking water and recreational guidance values. While the remaining samples collected along Jack in the Box Creek exceeded only the drinking water guidance values. As such the incidental ingestion of surface water through recreational activities, along the majority of the Jack in the Box Creek and within Wodonga Creek is not considered a risk. The level of risk associated with the surface water exceedances in close proximity to the base pathway will be the subject of a Human Health Risk Assessment.

PFAS concentrations in surface water were below drinking water and recreational water guidance values within Wodonga Creek, where swimming and boating are likely to occur and therefore based on the conditions assessed the incidental ingestion of surface water during recreational activities is not considered a risk. It is however noted that samples were collected during periods of high flow, and therefore may represent dilute conditions.

It is not uncommon in urban residential scenarios for groundwater to be used to supplement mains water for garden irrigation and to also fill or top up swimming pools. As the groundwater concentrations were below the adopted recreational screening guidance values, incidental ingestion when watering gardens, using groundwater for water play or filling swimming pools are not considered to present a risk (i.e. the Primary Contact Recreation beneficial use of groundwater is not precluded).

Due to the tendency for PFAS compounds to accumulate within biota, there is a potentially complete exposure pathway between the PFAS derived from the site, and the food people are catching within the catchment. The level of risk associated with this potentially complete pathway will be the subject of a Human Health Risk Assessment.

Commercial / industrial workers including general commercial / industrial worker, and maintenance / trench workers operating within the portions of the Jack in the Box Creek catchment downstream of the base and are potentially exposed via:

- Incidental ingestion of potentially impacted soil, sediment, surface water or groundwater.
- Inhalation of potentially impacted dust.

Soil and sediment concentrations were below human health commercial / industrial screening guidance values, and the below human health open space screening guidance values. Therefore, the incidental ingestion of potentially impacted soils and sediments and the inhalation of potentially impacted dust are not considered a risk.

PFAS concentrations in surface water were highest closest to the base with two samples collected immediately downstream of the base exceeding both human health drinking water and recreational guidance values. While the remaining samples collected along Jack in the Box Creek exceeded only the drinking water guidance values. As such, the incidental ingestion of surface water through occupational activities along the majority of the Jack in the Box Creek and within Wodonga Creek are not considered a risk. The level of risk associated with the surface water Tier 1 screen value exceedances in close proximity to the base pathway will be the subject of a Human Health Risk Assessment.

There are five licenced groundwater domestic / stock and three irrigation extraction bores within the Jack in the Box Creek catchment (Figure 1) to the north-west (i.e. down-gradient) of South Bandiana. The WUS responses received indicated extraction was occurring at only one property in the Jack in the Box...
Creek catchment, where groundwater was used for irrigating an aesthetic garden on a commercial / industrial property. As the PFAS concentrations up-gradient of this location were below the recreational water screening guidance values, the use of groundwater for garden irrigation and the potential for exposure through incidental ingestion is not considered to present a risk.

As the groundwater concentrations were below the adopted recreational screening guidance values, incidental ingestion that could occur through future commercial or industrial use of groundwater, or being exposed during excavation works which encounter groundwater, are not considered to present a risk (i.e. the industrial / commercial beneficial use of groundwater is not precluded).

**Off-base Ecological Receptors**

Based on the primary sources and the extent and nature of the secondary sources of PFAS contamination, the following potential SPR linkages to off-base ecological receptors have been identified:

- **Terrestrial or aquatic ecosystems** including flora and / or fauna which may be exposed to PFAS impacts off the base via:
  - Direct contact with and / or uptake of contaminants from soil, sediment or surface water.
  - Ingestion including eating impacted biota (including incidental ingestion of soil / sediment adhering to plants / grass) and drinking impacted surface water.
  - Ingestion of greater PFAS concentrations by higher trophic level predatory species due to the tendency for PFAS compounds to bioaccumulate and biomagnify within ecosystems.

Concentrations of PFAS were above the adopted ecological screening guidance values for soil, sediment, surface water and groundwater in the off-base Jack in the Box Creek catchment. The level of risk associated with the exceedances of the adopted ecological screening values will be the subject of an Ecological Risk Assessment.
Plate 9: Jack in the Box Creek On-base Human Receptors CSM Flow Chart
Plate 10: Jack in the Box Creek Off-base Human Receptors CSM Flow Chart
10.2  Kiewa River Catchment

10.2.1  Source Areas

The Kiewa River catchment includes the eastern portion of South Bandiana, North Bandiana and East Bandiana. A discussion of surface water flow is provided in Section 6.4 and further detail is provided within the description of each source area in Section 9.1. The groundwater flow direction is discussed in Section 6.6 and inferred contours are shown on Figure 8A. Based on site observations of topography and formed drainage channels, site service diagrams which include the stormwater pipe network, and groundwater elevations, the Kiewa River catchment receives the following:

- Surface drainage from Source Areas 8 and 9.
- Surface drainage from portions of Source Area 5.
- Surface drainage and groundwater flow from Source Areas 10 to 15 (Figure 10).

It is noted that groundwater from Source Areas 8 and 9 may also contribute to the Kiewa River catchment, however, the location of the groundwater divide is somewhat uncertain due to the absence of groundwater data within the eastern portion of South Bandiana.

Based on the source area assessments undertaken, it is considered that Source Area 8 (Section 9.1.8) is not PFAS impacted.

10.2.2  Nature and Extent of Contamination

Soil

Soil samples were collected from within the source areas contributing to the Kiewa River catchment and from general coverage areas across the bases where the land use was considered to be open space or commercial / industrial. Soil samples were also collected from the Bandiana Primary School and Bandiana Neighbourhood House, both of which are considered to be sensitive receptors. Soil samples were also collected from along the portion of the unnamed creek which flows through the residential estate to the east of North Bandiana.

PFAS was detected in the on-base soil samples, with higher concentrations generally identified in close proximity to source areas compared to those collected from on-base general coverage areas including along the base boundaries. The highest concentrations of PFAS in soil were identified within Source Area 5 (Petroleum Platoon – Fuel Handling Facility at South Bandiana, Figure 11D) and Source Area 13 (Fire Station – Current at East Bandiana, Figure 11I), with comparatively minor concentrations of PFAS identified in soil in Source Areas 10, 11 and 12 on North Bandiana, and Source Areas 14 and 15 on East Bandiana. Low concentrations of PFAS were also identified in the off-base soil samples.

PFOS was the dominant PFAS compound detected in on-base and off-base samples, with concentrations of PFOA, PFHxS, PFHxA, PFPeA, PFHpS, PFPeS and PFBS consistently detected at significantly lower concentrations. Concentrations of 6:2 FtS were detected at four locations including MW333 and SS311 (Source Area 5, Petroleum Platoon – Fuel Handling Facility), BH321 (Source Area 13, Fire Station - Current) and MW354 (Source Area 15).

Concentrations of PFAS generally decreased at depth within the soil profile or remained similar to surface or near surface concentrations.

Concentrations of PFAS detected in soil were generally below the adopted human health guidance values for the relevant land use. The following is noted in relation to PFAS concentrations and associated human health guidance values:
PFOS+PFHxS concentrations were below the commercial / industrial human health soil guidance values for the on-base samples collected within the Kiewa River catchment. Concentrations of PFOS+PFHxS exceeded open space human health guidance values at two locations including SS311 (12.6 mg/kg) located in Source Area 5 (Petroleum Platoon – Fuel Handling Facility at South Bandiana) in front of Building 298, where fire extinguishers were formerly emptied, and BH321 (2.27 mg/kg at surface and 3.3 mg/kg at 1.5 m bgl) located in Source Area 13 (Fire Station – Current at East Bandiana) where equipment testing and training exercises using AFFF were formerly undertaken. Both areas were open ground and are considered to fall within commercial / industrial land use.

PFOA concentrations were below human health residential soil guidance values for on-base samples collected within the Kiewa River catchment. The maximum PFOA concentration detected was 0.06 mg/kg in SS311 located in Source Area 5 (Petroleum Platoon – Fuel Handling Facility at South Bandiana).

On North Bandiana, PFOS+PFHxS for one sample from BH314 within Source Area 10 (Former Unit Training Area at North Bandiana) and one sample from BH312 within Source Area 12 (Armoured Vehicle Maintenance Training at North Bandiana), exceeded the residential soil guidance values. These sample locations are not near the Bandiana Neighbourhood House, the primary school or the on-base accommodation facilities. The remaining soil samples reported PFAS concentrations were below residential soil guidance values.

PFAS concentrations in samples collected from sensitive receptors including the Bandiana Primary School and the Bandiana Neighbourhood House were below residential human health soil guidance values.

PFAS concentrations in off-base soil samples were below residential and open space human health guidance value.

Exceedances of the interim direct open space (1 mg/kg) and indirect residential / parkland (0.01 mg/kg) soil ecological guidance values for PFOS were noted within Source Area 5 (Petroleum Platoon – Fuel Handling Facility at South Bandiana) in a grassed area used for training (MW334 and SS312). This area was often observed to contain kangaroos. Exceedances of the interim indirect commercial / industrial (0.14 mg/kg) soil ecological guidance values for PFOS were also noted in Source Area 5 near Building 298 used for warehousing (MW333 and SS311) and in Source Area 13 (Fire Station – Current at East Bandiana)

Concentrations of PFOS did not exceed open space / residential ecological guidance values for samples collected from off-base locations, on-base sensitive receptors or from on-base general coverage areas.

**Groundwater**

The groundwater wells installed and sampled within the Kiewa River catchment were installed within three geological units. Groundwater wells on South Bandiana and the north and western portion of North Bandiana were installed within the Shepparton Colluvium. Groundwater wells on East Bandiana and the eastern and southern portion of North Bandiana were installed within the Shepparton Fluvium, and groundwater wells installed along the Kiewa River were installed within the Coonambigdal Fluvium.

Low concentrations of PFAS were detected in two groundwater wells installed within the Shepparton Colluvium on South and North Bandiana, including an existing well BH111 in Source Area 9 and MW342 in Source Area 12. The existing groundwater well BH111 is installed within perched water and is located to the north of a POL store / shed (Building 488). Concentrations of PFOS+PFHxS (1.71 µg/L) detected in BH111 exceeded human health drinking water and recreational water guidance values. Concentrations of PFOS+PFHxS (0.09 µg/L) detected in MW342 exceeded human health drinking water guidance values.
Concentrations of PFAS were below the laboratory LOR for the boundary and general coverage wells installed on South Bandiana (MW335, MW337 and MW341). PFAS was also below the laboratory LOR for boundary and general coverage wells installed on North Bandiana (MW339, MW340, MW346 and MW363).

However, one groundwater well installed in the Shepparton Fluvium along the unnamed creek (MW345), reported concentrations of PFOS+PFHxS (0.3 µg/L) exceeding the human health drinking water guidance values. It is noted that the groundwater well installed further downstream where the unnamed creek exits North Bandiana (MW346) did not report concentrations of PFAS above the laboratory LOR. The absence of PFAS reported in MW346 may be due to the placement of the screen as both groundwater wells were installed within the same geological unit and exhibited similar water levels, however, MW346 is screened approximately 3.5 m deeper than MW345.

Concentrations of PFAS in groundwater were significantly higher in groundwater wells installed in the Shepparton Fluvium across East Bandiana in comparison to groundwater wells installed on South and North Bandiana. PFAS was detected in 22 of the 23 groundwater wells sampled across East Bandiana. Concentrations were below the laboratory LOR for one deep groundwater well (MW21) located along the eastern site boundary. The dominant PFAS compound detected across East Bandiana was PFHxS followed by PFOS, PFOA, PFHxA, PFHpA, PFPeA, PFHxS, PFPeS and PFBS were also consistently detected. Low concentrations of 6:2 Fts were reported in eight samples, generally from within source areas.

Concentrations of PFOS+PFHxS across East Bandiana exceeded human health drinking water and / or recreational water guidance values, and PFOA exceeded human health water guidance values in six groundwater wells.

Concentrations of PFAS in the nested groundwater wells sampled generally decreased with depth. The highest concentrations of PFAS detected across East Bandiana were in the shallow groundwater wells MW06-A, BH01, BH02 and MW350(S) installed in Source Area 13 (Current Fire Station). Concentrations of PFOS+PFHxS in the shallow groundwater wells ranged between 26.5 µg/L in up-gradient monitoring well MW06-A to 118 µg/L in monitoring well BH02 which exceeded human health drinking water and recreational water guidance values. Concentrations of PFOA which ranged between 1.37 µg/L (MW06-A) to 6.8 µg/L (BH02) in shallow groundwater wells also exceeded human health drinking water and / or recreational water guidance values. PFAS concentrations in the deep groundwater well (MW350(D)) were significantly lower than concentrations detected in shallow wells within Source Area 13.

Concentrations of PFAS in the down- and cross-gradient groundwater wells located to the south (MW29), east (MW12) and north-east (MW353) of Source Area 13 were considerably lower compared to groundwater wells within Source Area 13. Nevertheless, concentrations of PFOS+PFHxS in these groundwater wells ranged between 0.37 µg/L (MW12) and 8.98 µg/L (MW353) which exceeded human health drinking water and / or recreational water guidance values. Groundwater wells located further towards the east within Source Area 14 (Former Unit Training Building 592), including two wells along the central-eastern boundary (MW16 and MW35) generally exhibited slightly higher concentrations than MW353 indicating that AFFF was likely used in this area and is likely migrating off-base. It is noted that the highest concentrations of PFAS reported within Source Area 14 were in the intermediate well (MW43) and deep well (MW42).

Groundwater wells located along the north-eastern (MW351 and MW352) and south-eastern boundary (MW18, MW20, MW21, MW34, MW46, MW47 and MW354) of East Bandiana generally exhibited the lowest PFAS concentrations detected across East Bandiana. However, concentrations of PFOS+PFHxS exceeded human health drinking water and / or recreational water guidance values in a number of these boundary wells indicating that PFAS contamination is likely migrating off-base.
Three off-base groundwater wells (MW356, MW357 and MW358) were installed along the Kiewa River banks to assist in determining the relationship between groundwater and surface water within the Kiewa valley. The off-base concentrations of PFAS detected were considerably lower in comparison to on-base concentrations across East Bandiana. However, like the samples collected on-base, these samples also were also dominated by PFHxS concentrations followed by PFOS. MW357 (0.111 µg/L) installed at the confluence of the unnamed creek flowing though North Bandiana and a residential estate exceeded drinking water guidance values for PFOS+PFHxS values (therefore precluding some protected beneficial uses e.g. domestic and stock watering) but was below recreational water guidance values. Concentrations of PFOS also exceeded ecological screening guidance values at all three locations.

One off-base groundwater well (MW347) was installed within the residential estate to the east of North Bandiana. The well was located down-gradient of a former sewage treatment plant. Similar to the on-base groundwater samples collected, concentrations of PFAS were dominated by PFHxS concentrations followed by PFOS. PFAS concentrations in groundwater were below the human health drinking water and recreational water screening guidance values, however, exceeded the ecological screening guidance values.

PFAS in point of use groundwater samples (including BH1 to BH3 and OTH001) collected from south of East Bandiana (i.e. upstream), generally reported concentrations of a similar magnitude and composition to those off-base wells installed along the Kiewa River banks (MW356 to MW358). This indicates that groundwater in close proximity to the Kiewa River bank may represent or be influenced by the seasonal high surface water flows.

**Surface Water**

A total of 51 surface water sample locations were proposed on-base within the Kiewa River catchment, however, only 32 samples were able to be collected as the drainage channels proposed for sampling were often observed to be dry during the investigation.

Surface water samples were collected from 41 off-base locations including an additional sample from the confluence of the unnamed creek and the Kiewa River (SW462), and three additional samples within the residential estate to the east of North Bandiana (SW464, SW465 and SW466). Surface water samples were not able to be collected at two proposed locations (SW/SD413 and SW/SD445) as access to the properties was not obtained. Of the 41 off-base surface water sample locations, 14 were from within the Kiewa River and its tributary (Middle Creek), five were from the portion of the unnamed creek flowing through the residential estate, four were from the portion of the unnamed creek flowing through the Kiewa River floodplain, 11 were from oxbow lakes on the Kiewa River floodplain, five were from within the Murray River, and two were from stormwater settling ponds. In addition, three point of use surface water samples were collected from stock dams.

PFAS was detected in the 32 on-base samples able to be collected including samples collected from general coverage areas such as the South Bandiana golf course ponds which were not identified to be in close proximity to source areas. Concentrations of PFOS+PFHxS exceeded the human health drinking water guidance values in 26 of 32 on-base surface water samples, with six of those samples also exceeding recreational water guidance values.

PFOS was the dominant PFAS compound detected in on-base samples and samples from within the Kiewa and Murray River channels, Middle Creek and unnamed creek with slightly lower concentrations of PFHxS consistently detected. Contrary to the on-base and in-channel samples, samples collected from oxbow lakes on the Kiewa River floodplain were generally dominated by PFHxS followed by slightly lower concentrations of PFOS. Concentrations of PFOA, PFHxA, PFHpA, PFDA, PFPeA, PFNA, PFHpS, PFPeS and PFBS were consistently detected at significantly lower concentrations in the on-base and off-base surface water samples.
in comparison with PFOS and PFHxS. Concentrations of 6:2 FtS were detected at 13 on-base sample locations, primarily on South Bandiana, and at seven off-base sample locations.

The highest on-base PFAS concentrations were identified in Source Area 5 (Petroleum Platoon Fuel Handling Facility) in the drainage channel running parallel to the northern boundary of South Bandiana and flowing into the stormwater ponds (wetlands) at the entrance to South Bandiana. The concentrations of PFOS+PFHxS detected ranged between 2.8 µg/L (SW342) and 6.8 µg/L (SW340) which exceeded both human health drinking water and recreational guidance values. PFAS concentrations in surface water within the six samples collected from the stormwater ponds (wetlands) were slightly lower than those detected in Source Area 5, with all six samples exceeding the human health drinking water guidance values for PFOS+PFHxS, and three samples exceeding the recreational guidance values. Concentrations of PFAS generally decreased from the western stormwater ponds (wetlands) through the eastern ponds and downstream along the unnamed creek which flows through North Bandiana towards Whytes Road and through a residential estate to the east. The concentration of PFOS+PFHxS in the sample (SW375) collected from the unnamed creek at the boundary of North Bandiana before the creek passes underneath Whytes Road and enters the residential estate was 0.29 µg/L which exceeds human health drinking water guidance values but is less than the human health recreational water guidance value. It is noted that a yabby trap was observed in the off-base portion of the unnamed creek along Whytes Road.

Five off-base samples were collected from the unnamed creek from the portion which flows through the residential estate (SW406, SW408, SW409, SW410 and SW464), and a further four off-base samples were collected on the floodplain from between the eastern edge of the residential estate and the confluence of the unnamed creek with the Kiewa River (SW411, SW412, SW415 and SW462). The concentrations of PFOS+PFHxS in seven of these samples exceeded human health drinking water guidance values (but below the human health recreational water guidance values) and were generally of a similar magnitude to SW375 which was collected from the boundary of North Bandiana. Grazing stock (cows) and wild deer were observed in this area during the investigation.

Surface water samples collected from on-base at East Bandiana were generally from engineered stormwater ponds (settling ponds) or from a drainage channel running west to east along the Test Track Facility. Concentrations of PFOS+PFHxS in the five surface water samples collected ranged between 0.0416 µg/L (SW378 collected from a stormwater pond (settling pond)) to 0.343 µg/L (SW388 collected from the eastern extent of the drainage channel on the Kiewa River floodplain).

The eight off-base surface water sample locations (SW395, SW396, SW397, SW399, SW400, SW401, SW403 and SW405) situated directly east and north-east of East Bandiana within oxbows on the Kiewa River floodplain generally exhibited the highest concentrations of PFAS within the off-base Kiewa River catchment. Concentrations of PFOS+PFHxS from the eight sample locations exceeded human health drinking water guidance values. The highest concentration of PFOS+PFHxS detected was 12.8 µg/L at sample location SW397, followed by SW399 (1.06 µg/L) and SW400 (0.826 µg/L) which all also exceeded human health recreational water guidance values. The elevated PFAS concentrations in these samples are likely attributed to two stormwater pipes which drain East Bandiana and directly feed the oxbow lakes, overland surface water runoff, and groundwater seepage coming from East Bandiana.

Off-base surface water samples were also collected from one upstream oxbow (SW442) and two oxbows on the eastern bank on the Kiewa River (SW444 and SW446). The PFAS concentrations within these oxbows were low in comparison to the concentrations of PFAS from the oxbows located directly east and north-east of East Bandiana. The detection of PFAS in the upstream oxbow indicates a potential background source of PFAS, and detections of PFAS in oxbows on the opposing eastern floodplain confirmed the distribution of PFAS impacts within the Kiewa River valley, through flood events and / or groundwater and surface water interactions.
Concentrations of PFAS within the Kiewa River main channel, Middle Creek and the Murray River were generally considerably lower than concentrations of PFAS detected on-base, within the oxbow lakes and within the unnamed creek draining from North Bandiana. Concentrations of PFOS+PFHxS were below human health drinking water and recreational water guidance values within the main Kiewa River channel. Low concentrations of PFAS were detected in samples collected within the Kiewa River upstream of East Bandiana (SW389, SW390 and SW391) and in samples collected from the Murray River upstream of the Kiewa River confluence (SW421, SW440 and SW441), suggesting the potential for background sources of PFAS. It is noted that while the concentrations of PFAS detected were generally below the adopted human health drinking and recreational screening guidance values, the samples were collected during periods of high flow.

Concentrations of PFOS were above the adopted ecological screening guidance values within a number of on-base and off-base samples collected. Although it is noted that many of these exceedances were of the conservative 99% level of protection screening guidance value, which have been adopted to allow for the potential for bioaccumulation.

**Sediment**

A total of 51 sediment sample locations were proposed for collection on-base within the Kiewa River catchment. Two samples were not able to be collected due to the presence of concrete lined drains / creeks.

Sediment samples were collected from 42 off-base locations including an additional sample from the confluence of the unnamed creek and the Kiewa River (SD462) and three additional samples within the residential estate to the east of North Bandiana (SD464, SD465 and SD466). Sediment samples were not able to be collected at two proposed locations (SD413 and SD445) as access to the properties was not obtained. Of the 42 off-base sediment sample locations, 14 were from within the Kiewa River and its tributary (Middle Creek), six were from the portion of the unnamed creek flowing through the residential estate, four were from the portion of the unnamed creek flowing through the Kiewa River floodplain, 11 were from oxbow lakes on the Kiewa River floodplain, five were from within the Murray River, and two were from stormwater settling ponds. In addition, three point of use sediment samples were collected from stock dams.

PFAS was detected in 46 of the 49 on-base sediment samples collected including in samples collected from general coverage areas such as the South Bandiana Golf Course Ponds which were not near a source area. The concentrations of PFOS+PFHxS and PFOA detected in on-base sediment samples were below the adopted human health guidance values open space or commercial / industrial guidance values.

Like surface water, PFOS was the dominant PFAS compound detected in on-base sediment samples, with concentrations of PFDS, PFOA, PFHxS, PFHxA and PFDA consistently detected at significantly lower concentrations. Contrary to surface water samples, off-base sediment samples collected from oxbow lakes on the Kiewa River floodplain generally exhibited slightly higher or similar concentrations PFOS compared to PFHxS. One on-base sediment sample reported detections of 6:2 FtS (SD341 in Source Area 5 – Petroleum Platoon Fuel Handling Facility) with all other samples analysed below the laboratory LOR.

Concentrations of PFAS in on-base sediment samples collected from South Bandiana were generally higher near source areas with the highest concentration of PFOS+PFHxS detected in sample SD341 (Source Area 5 – Petroleum Platoon Fuel Handling Facility). In contrary, PFAS concentrations in sediment samples collected from North Bandiana were generally lower or similar within source areas compared to concentrations along the main drainage channels including the unnamed creek, which indicates that sediment from South Bandiana is likely being entrained and transported downstream. The highest concentrations of PFOS+PFHxS on North Bandiana were detected in sample SD370 (0.0227 mg/kg) located approximately mid-way along the unnamed creek and in the sample SD375 (0.0118 mg/kg) collected from the unnamed creek at the boundary of North Bandiana before the creek passes underneath Whytes Road and enters the residential estate to the east. It is
noted that both samples exceed human health residential soil guidance values. However, the likelihood of regular flooding along the unnamed creek is considered to be low given the relatively recent construction of the houses and re-shaping of the creek within the development area. Further, the 1:100 year flood overlay does not include the residential estate, indicating that the frequency of flooding is less than 1:100 year average rainfall event (Figure 5).

Six off-base samples were collected from the unnamed creek from the portion which flows through the residential estate (SD406, SD407, SD408, SD409, SD410 and SD464), and four off-base samples were collected on the floodplain from between the eastern edge of the residential estate and the confluence of the unnamed creek with the Kiewa River (SD411, SD412, SD415 and SD462). Concentrations of PFOS+PFHxS in these ten samples were below human health residential soil guidance values. Overall, like surface water, PFAS concentrations in sediment appear to decrease in a downstream direction from South Bandiana to the Kiewa River via the unnamed creek. It is however noted that concentrations of PFAS in sediment were slightly higher in samples collected from the unnamed creek where it flows through the floodplain in comparison to samples collected from the unnamed creek where it flows through the residential estate.

Sediment samples collected on-base from East Bandiana were generally from engineered stormwater ponds (settling ponds) or from a drainage channel running west to east along the Test Track Facility. Concentrations of PFAS were highest in the two samples collected from Source Area 13 (Current Fire Station) and in the two samples collected directly south of the Current Fire Station from the drainage channel running west to east along the Test Track Facility. The concentrations of PFOS+PFHxS in these four samples ranged between 0.0163 mg/kg (SD380 located in Source Area 13) and 0.0349 mg/kg (SD381 located in the drainage line).

Overall, concentrations of PFAS in sediment from the samples collected from East Bandiana are like those collected from sediment sample locations situated directly east and north-east of East Bandiana within oxbows on the Kiewa River floodplain (SD395, SD396, SD397, SD399, SD400, SD401, SD403 and SD405). This is contrary to surface water PFAS concentrations, which were generally much greater in the oxbow lakes in comparison to on-base samples.

PFAS concentrations in the sediment samples collected from within the Kiewa River main channel, and the Murray River were below the laboratory LOR. Therefore, similar to surface water, PFAS concentrations in the sediment samples collected from within the river / creek channels are generally considerably lower than concentrations of PFAS detected on-base and within the oxbow lakes. It is however important to note that the majority of samples collected from within channels were described as predominately containing sand, compared to samples collected from on-base locations and oxbows which predominately contained fine grained silts and clays.

10.2.2.1 Pathways

Based on the site setting, there is potential for the PFAS contamination to be transported via either soil / sediment, surface water, groundwater or biota. The results of the investigations indicated the key pathway for the migration of PFAS impacts away from the source areas identified on South Bandiana and North Bandiana within the Kiewa River catchment is via surface water (i.e. via water travelling down the creeks etc.). However, at East Bandiana the key pathways appear to be via groundwater and surface water.

Based on the depth to groundwater within the upper portions of the Kiewa catchment (i.e. beneath South Bandiana and North Bandiana), direct groundwater and surface water interaction are unlikely to be occurring, and based on the topography and the inferred groundwater contours, at the time of the investigations Middle Creek appeared to be recharging groundwater (i.e. “giving”).

However, based on the topography, inferred groundwater contours and PFAS concentrations, surface water and groundwater interaction is occurring within the oxbow lakes located to the east of East Bandiana, and
near the confluence of the unnamed creek and the Kiewa River. The nature of the surface water and groundwater interaction within these areas is likely to be variable based on the seasonal water levels within the Kiewa River and within the oxbow lakes. During the seasonal high water, it is inferred that the Kiewa River would be recharging groundwater (i.e. "giving"). However, during the low water season this may reverse, and groundwater would be discharging into the Kiewa River (i.e. "receiving"). These seasonal changes are not fully understood.

10.2.3 Receptor Linkages

The SPR linkages for the Kiewa River catchment have been separated into on-base and off-base areas, and are further discussed and represented in the flow charts below (Plate 11 and Plate 12).

On-base Human Receptors

Based on the primary sources and the extent and nature of the secondary sources of PFAS contamination across the base, the following potential SPR linkages to on-base human receptors have been identified:

- On-base residents or sensitive receptors who live or visit the base and are potentially exposed via:
  - Incidental ingestion of impacted soil and / or water on the base and eating potentially impacted biota grown or caught on the base.
  - Inhalation of impacted dust.
  - Eating potentially impacted biota grown within the catchment area, including home grown foods, such as fruit and vegetables and livestock (sheep, chickens / eggs).

PFAS source areas were not identified within (or in proximity to) the on-base residential area in the Kiewa River catchment located on North Bandiana. One soil sample from Source Area 10 (Former Unit Training between Warehouse 1 and 2), one soil sample from Source Area 12 (Armoured Vehicle Maintenance Training) and two sediment samples along the unnamed creek from within the Warehouse Area exceeded the residential soil guidance values. Source Areas 10 and 12 are considered commercial / industrial land use areas and are positioned down-gradient of the on-base residential area, and the unnamed creek is an open space area.

The reported soil PFAS concentrations from samples collected at the Bandiana Primary School and Bandiana Neighbourhood House were below human health low density residential screening guidance values, and therefore, based on the activities occurring on the site, including the consumption of home grown vegetables, does not present a risk.

Based on the observations and information provided during the site investigations the on-base residential areas do not include the production or consumption of home grown foods, such as fruit and vegetables, or livestock (chickens / eggs). Further, the hunting or catching of game (fish, kangaroo or deer) are not permitted on the base. Therefore, the potential exposure to on-base residents or personnel through the consumption of foods produced on the base is considered an incomplete exposure route. Management actions may need to be considered to ensure these restrictions are continued to be enforced into the future.

A portion of South Bandiana along the base of Bears Hill and a portion of North Bandiana to the southeast of the unnamed creek are leased to a licenced grazier for sheep grazing. Sheep on South Bandiana have access to a dam located in the south-eastern portion of the grazing area which is fed by surface water runoff from Bears Hill – up gradient of the identified Source Areas, and a municipal-supply fed water trough. Sheep on North Bandiana are watered from a municipal-supply fed water trough. It is understood that sheep on North Bandiana do not have access to the unnamed creek. Due to the
tendency for PFAS compounds to accumulate within biota, the level of risk associated with this potentially complete pathway will be the subject of a Human Health Risk Assessment.

PFAS concentrations in surface water exceeded the drinking water guidance values in most samples collected from both within the source areas and along drainage lines within the on-base Kiewa River catchment. A small number of samples also exceeded the recreational water guidance values. Based on the information provided by Defence, surface water on the base is not used for recreational activities such as swimming, and children do not live on the base. As such the incidental ingestion of surface water is considered unlikely, and the PFAS concentrations in the surface water are not considered to present a risk to on-base residents or sensitive receptors as the exposure link is considered incomplete. Management actions may need to be considered to ensure this exposure is continued to be minimised.

Concentrations of PFAS in groundwater exceeding drinking water and recreation water guidance values were detected on East Bandiana, with generally lower concentrations of PFAS detected across North Bandiana and the eastern portion of South Bandiana. The groundwater within the Kiewa River catchment is classified as Segment A1 for East Bandiana, and Segment B for North and South Bandiana, with potable water supply considered the most sensitive protected beneficial use. However, on-base extraction of groundwater is not occurring, and future groundwater extraction is considered unlikely given the availability of mains water. Therefore, the potential exposure through the incidental ingestion of extracted groundwater on the base is considered an incomplete exposure route. Management actions may need to be considered to restrict the future extraction of groundwater from the site.

- **On-base workers, army personnel and site visitors** who work or visit the base and are potentially exposed via:
  - Incidental ingestion of soil and / or water on the base.
  - Inhalation of dust.

The soil PFAS concentrations in Source Area 5 and Source Area 13 exceeded the adopted open space soil screening guidance values, however, were below the adopted commercial / industrial soil screening guidance values. Given that field training activities do not occur in the immediate vicinity of these sample locations, it is considered that commercial / industrial soil screening guidance values is most appropriate, and the concentrations do not present a risk. The remaining reported soil and sediment PFAS concentrations were below human health open space and commercial / industrial screening guidance values, and therefore do not present a risk.

PFAS concentrations in surface water exceeding the recreational water guidance values were identified in portions of the upper Kiewa River catchment (i.e. within and near South Bandiana). While unlikely to present a significant risk, there is a potential concern if people accidently (or routinely) swallow the impacted surface water. This may happen when people are either involved in maintenance activities or involved in training which use or involve the exposure to surface water (as discussed within Section 10.1.3). While unlikely to present a significant risk, it is important to ensure appropriate health and safety controls are implemented when people are either involved in maintenance activities, or involved in training which use and/ or involve the exposure to surface water.

The groundwater on the base near the unnamed creek flowing through North Bandiana ranged from 2 to 4 m bgl, while the depth to groundwater on the remaining portions of the base within the Kiewa River catchment generally ranged between approximately 5 m bgl at the north-eastern extent of East Bandiana to 20 m bgl on South Bandiana. As such, there are portions of the Kiewa River catchment where there is potential for groundwater to be encountered during excavation or construction works. And PFAS concentrations in groundwater on East Bandiana exceeded the recreational water screening guidance values. While unlikely to present a significant risk, it is important to ensure appropriate health and safety
controls are implemented when people are either involved in maintenance or construction activities, which encounter groundwater and/or involve the potential exposure to groundwater.

**On-base Ecological Receptors**

Based on the primary sources and the extent and nature of the secondary sources of PFAS contamination, the following potential SPR linkages to ecological receptors have been identified:

- **Terrestrial or aquatic ecosystems** including flora and fauna which may be exposed to PFAS impacts on the base via:
  - Direct contact with and/or uptake of contaminants from soil, sediment or surface water.
  - Ingestion including fauna eating impacted biota (including incidental ingestion of soil/sediment adhering to plants/grass) and drinking impacted surface water.
  - Ingestion of greater PFAS concentrations by higher trophic level predatory species due to the tendency for PFAS compounds to bioaccumulate and biomagnify within ecosystems.

Concentrations of PFAS were above the adopted ecological screening guidance values for soil, sediment, and surface water in the on-base Kiewa River catchment. The level of risk associated with the exceedances of the adopted ecological screening values will be the subject of an Ecological Risk Assessment.

**Off-base Human Receptors**

Based on the extent and nature of the secondary sources of PFAS contamination within the off-base investigation area, the following potential SPR linkages to off-base human receptors have been identified:

- **Off-base sensitive receptors** including people who either live, visit, or attend school or childcare facilities within the portions of the Kiewa River catchment downstream of the base and are potentially exposed via:
  - Drinking potentially impacted water.
  - Incidental ingestion of potentially impacted soil, sediment, surface water or groundwater.
  - Inhalation of potentially impacted dust.
  - Eating potentially impacted biota grown or reared within the catchment area, including home grown or agriculturally produce such as:
    - Fruit and vegetables which may have been irrigated with groundwater or surface water extracted from oxbows or rivers.
    - Livestock (cattle and chickens, including eggs) which may drink directly from oxbows or flowing channels, graze on impacted pasture (which may include incidental ingestion of soil/sediment adhering to plants/grass) or drink water from dams/troughs water in which was extracted from potentially impacted oxbows, rivers/creeks or groundwater.

PFAS concentrations in off-base surface water samples from oxbow lakes to the east and north-east of East Bandiana located along the western bank of the Kiewa River floodplain exceeded the drinking water and recreational water screening guidance values. The level of risk in these areas will be the subject of a Human Health Risk Assessment.

Concentrations of PFAS within the unnamed creek flowing from Whytes Road along the eastern boundary of North Bandiana and towards the Kiewa River (through a residential estate) were below human health guidance values except for seven surface water samples which exceeded the drinking
water guidance values. The level of risk in these areas will be the subject of a Human Health Risk Assessment.

Based on the conditions assessed, the concentrations of PFAS within the Kiewa River main channel were below human health drinking water guidance values. Therefore, based on the conditions assessed, water which may be extracted from the Kiewa River by residents with river access would be suitable for drinking. Additionally, based on outcomes of other studies conducted in Australia, concentrations of PFAS in water equivalent to the drinking water guidance values were considered safe to use for garden, poultry and stock watering. The Human Health Risk Assessment will provide the mechanism of validating these findings considering the site-specific data collected.

The groundwater within the off-base Kiewa River is classified as Segment A1, where potable water is considered the most sensitive protected beneficial use. Concentrations of PFAS in groundwater above the drinking water guidance values were detected in a groundwater monitoring well on the Kiewa River floodplain near the confluence of the Kiewa River and the unnamed creek. Additionally, groundwater concentrations along the eastern (down-gradient) boundary of East Bandiana also reported groundwater concentrations exceeding the adopted drinking water and recreational water use screening guidance values.

While there are no registered bores for domestic purposes within the Kiewa River catchment, data from the WUS identified that groundwater on a property to the east of the Kiewa River is being extracted and used for drinking, as well as irrigation of home grown produce and livestock. Similarly, groundwater on a property to the south of East Bandiana also reported using groundwater for garden irrigation including watering home grown foods, such as fruit and vegetables, and livestock. The concentrations of PFAS in water from the extraction bores were less than drinking water and recreational water screening guidance values.

The extent of groundwater impacts above the drinking water screening guidance values have not been delineated to the east and north-east of East Bandiana, and the extent of groundwater impacts near the unnamed creek east of North Bandiana have not been delineated.

Due to the availability of mains water, and based on the results of the WUS, the widespread extraction of groundwater is not expected to be occurring within the catchment. While it was not confirmed if the use of groundwater as potable water was being realised, the PFAS concentrations identified in the catchment likely preclude this beneficial use. Overall, given the use of groundwater for drinking water is unconfirmed and the availability of mains water throughout the catchment, further assessment through the Human Health Risk Assessment is currently not proposed.

Due to the tendency for PFAS compounds to accumulate within biota, there is a potentially complete exposure pathway between the PFAS sourced from the site, and the food people are consuming from within the catchment. The level of risk associated with this potentially complete pathway will be the subject of a Human Health Risk Assessment.

- **Recreational users** including people using public open recreational spaces within the Kiewa River catchment adjacent and downstream of the base and are potentially exposed via:
  - Incidental ingestion of potentially impacted soil, sediment, surface water or groundwater.
  - Inhalation of potentially impacted dust.
  - Eating potentially impacted wild biota caught within the catchment area, including recreationally caught seafood including fish and yabbies, and hunted deer or ducks.
Soil and sediment concentrations were below human health open space screening guidance values. Therefore, the incidental ingestion of potentially impacted sediments and the inhalation of potentially impacted dust are not considered a risk.

PFAS concentrations in off-base surface water samples from oxbow lakes immediately to the east and north-east of East Bandiana located along the western bank of the Kiewa River floodplain exceeded recreational water guidance values. While these are generally located within agricultural areas, there is potential that residents or visitors to the area may swim in the oxbows. Therefore, the level of risk associated with this potentially complete pathway will be the subject of a Human Health Risk Assessment.

Based on the conditions assessed, PFAS concentrations in surface water samples from within the Kiewa River main channel, the flowing tributaries of the Kiewa River, and the Murray River main channel were below the adopted recreational water guidance values. Therefore, incidental ingestion of the water while swimming within the main flowing channels is not considered to present a risk. It is, however, noted that samples were collected during periods of high flow and may represent dilute conditions. The level of risk associated with potential concentrations during low water conditions will be the subject of a Human Health Risk Assessment.

Due to the tendency for PFAS compounds to accumulate within biota, there is a potentially complete exposure pathway between the PFAS derived from the site, and the food people are catching within the catchment. This includes the potential for people to be exposed through the consumption of foods caught, including fish and yabbies from within the oxbow lakes, the Kiewa River and unnamed creek, or foods hunted, including deer within the wider catchment, which may enter and / or drink / feed from oxbows, the Kiewa River and the unnamed creek. The level of risk associated with this potentially complete pathway will be the subject of a Human Health Risk Assessment.

Commercial / industrial workers including general commercial / industrial worker, and maintenance / trench workers operating within the portions of the Kiewa River catchment downstream of the base and are potentially exposed via:

- Incidental ingestion of potentially impacted soil, sediment, surface water or groundwater.
- Inhalation of potentially impacted dust.

Soil and sediment concentrations were below human health commercial / industrial screening guidance values. Therefore, the incidental ingestion of potentially impacted sediments and the inhalation of potentially impacted dust are not considered a risk.

PFAS concentrations in off-base surface water samples from oxbow lakes to the east and north-east of East Bandiana located along the western bank of the Kiewa River floodplain exceeded drinking water and recreational water guidance values, while the remaining samples off-base reported PFAS concentrations below the recreational water guidance values. As such the incidental ingestion of surface water through occupational activities, within the majority of river and creek channels, is not considered a risk. The level of risk associated with the exceedances of the Tier 1 screening values within the oxbow lakes will be the subject of a Human Health Risk Assessment.

There are currently no known groundwater extraction bores licenced for commercial or industrial purposes within the Kiewa River catchment. And commercial / industrial land use is limited, with most of land use located adjacent to or down-gradient of the base designated as residential, farming or conservation (Figure 3). The extent of groundwater impacts above the recreational water screening guidance values have not been delineated to the east and north-east of East Bandiana, and the extent of groundwater impacts near the unnamed creek east of North Bandiana have not been delineated. Based on the depths to groundwater observed on the base, there is potential for groundwater to be encountered.
during excavation or construction works in the areas east and north-east of East Bandiana. While unlikely to be a significant risk, it is important to ensure appropriate health and safety controls, are implemented when people are either involved in maintenance or construction activities, which encounter groundwater and/or involve the potential exposure to groundwater.

**Off-base Ecological**

Based on the extent and nature of the secondary sources of PFAS contamination, the following potential SPR linkages to off-base ecological receptors have been identified:

- **Terrestrial or aquatic ecosystems** including flora and fauna which may be exposed to PFAS impacts off the base via:
  - Direct contact with and/or uptake of contaminants from soil, sediment, surface water or groundwater for flora with deep root systems.
  - Ingestion including eating impacted biota (including incidental ingestion of soil/sediment adhering to plants/grass) and drinking impacted surface water.
  - Ingestion of greater PFAS concentrations by higher trophic level predatory species due to the tendency for PFAS compounds to bioaccumulate and biomagnify within ecosystems.

Concentrations of PFAS were above the adopted ecological screening guidance values for soil, sediment, surface water and groundwater throughout the off-base Kiewa River catchment. The level of risk associated with the exceedances of the adopted ecological guidance value will be the subject of an Ecological Risk Assessment.
Plate 11: Kiewa River On-base Human Receptors CSM Flow Chart
Plate 12: Kiewa River Off-base Human Receptors CSM Flow Chart
10.3 Areas of Uncertainty

10.3.1 Deviations from the SAQP

Groundwater

The following deviations from the SAQP relating to groundwater sampling are noted and discussed below:

- Groundwater wells MW318 (Source Area 2), MW320 (South Bandiana – general coverage), MW322 (Source Area 7) and MW333 (Source Area 5) could not be sampled as they were dry. Overall, this is not expected to have a significant impact on the conceptual understanding developed through the DSI (i.e. the SPR linkages) given that the groundwater wells are located up-gradient within the respective source areas, not near site boundaries, in areas where groundwater was generally greater than 20 m bgl and in areas where groundwater extraction was not occurring.

- Groundwater was not able to be sampled near the Bandiana Primary School, as the three wells formerly installed near the former POL (previously located adjacent to the school) were not able to be located due to recent construction activity. The last known sampling event of these wells was undertaken by Golder (2012). Overall this is not expected to have a significant impact on the conceptual understanding given that the depth to groundwater was approximately 17 m bgl (Golder, 2012) and there is no known groundwater extraction occurring.

- Proposed groundwater wells MW348 and MW349 at Source Area 13 (Fire Station – Current, East Bandiana) were not installed as newly installed groundwater wells BH01 and BH02 were identified and sampled. These wells were identified by Defence as replacement wells for former monitoring wells MW05 and MW07, which were destroyed when the carpark was constructed during 2014. The construction logs for BH01 and BH02 were not able to be obtained. It was observed that the wells were installed using 50 mm PVC and a comparison was made between the new wells (BH01 and BH02) and the destroyed wells (MW05 and MW07) as detailed in Table 16. The comparison between the wells indicates that BH01 and MW07, and BH02 and MW05 are similar in terms of geographical position and depth.

Table 16: Comparison of new and destroyed wells at Source Area 13 (Fire Station - Current)

<table>
<thead>
<tr>
<th>Well ID</th>
<th>Easting</th>
<th>Northing</th>
<th>Ground Level (m AHD)</th>
<th>TOC (m AHD)</th>
<th>Well Depth (m TOC)</th>
<th>Well Depth (m AHD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MW07¹</td>
<td>495304.04</td>
<td>5999591.43</td>
<td>167.080</td>
<td>167.488</td>
<td>10.95</td>
<td>156.538</td>
</tr>
<tr>
<td>BH01</td>
<td>495312.20</td>
<td>5999591.49</td>
<td>167.008</td>
<td>166.926</td>
<td>9.964</td>
<td>156.962</td>
</tr>
<tr>
<td>MW05¹</td>
<td>495264.47</td>
<td>5999611.17</td>
<td>166.833</td>
<td>167.604</td>
<td>11.23</td>
<td>156.374</td>
</tr>
<tr>
<td>BH02</td>
<td>495269.66</td>
<td>5999632.70</td>
<td>166.732</td>
<td>166.617</td>
<td>10.02</td>
<td>156.597</td>
</tr>
</tbody>
</table>

Notes:

(1) Well information obtained from Golder (2012)

- Groundwater well MW355, near the Baranduda WWTP was not installed as alternative, adjacent monitoring locations were available and were sampled. The construction logs for these wells were not able to be obtained.
**Surface Water**

A considerable number of surface water samples were not able to be collected during the investigation period. A comparison of the proposed samples to the completed sampling is as follows:

- **On-base:**
  - 10 of 39 proposed surface water samples were collected from within the Jack in the Box Creek catchment.
  - 32 of 51 proposed surface water samples were collected from within the Kiewa River catchment.

- **Off-base:**
  - 13 of 14 proposed surface water samples were collected along Jack in the Box Creek, including two additional samples not proposed in the SAQP.
  - 41 of 43 proposed surface water samples were collected from the Kiewa River catchment including four additional samples not proposed in the SAQP.

A large number of on-base surface water samples were not able to be collected during the investigation as the locations were observed to be dry. The locations observed to be dry were predominantly shallow, open drainage channels / swales which are featured across BMA to aid in the collection of stormwater runoff during heavy rainfall and allow runoff to be funneled towards creeks or stormwater ponds (wetlands). These drainage channels / swales are primarily found on South Bandiana, particularly in the Close Training area and on North Bandiana, mainly in the warehouse area, where there is little or no below ground stormwater pipe infrastructure.

Due to the mobility of PFAS, the surface water and sediment sampling program was scheduled at the beginning of the field work program (early-mid October) to help inform the potential distribution of PFAS within the investigation area. During this period, and during the remainder of the fieldwork program (late October and November) only minor rain events were experienced which were generally too small to produce significant runoff and subsequent ponded (or flowing) water in these drainage channels. Where surface water was able to be collected, it was generally from constructed ponds or dams, or from the more downstream drainage channels with a greater upstream catchment area.
It is noted that the periods during which water is ponded (or flowing) within the drainage channels across BMA is likely to be intermittent and of a short duration following moderate or heavy rain events where there is sufficient rainfall to saturate the ground surface, which is predominately grass across South and North Bandiana, and produce runoff. Given that the occurrence of this is likely to be intermittent and of a short duration, it is considered that potential human exposure to impacted water within drainage channels would be minimal.

Across the investigation area it was generally identified that concentrations of PFAS in surface water decreased in a downstream direction. Given the absence or lack of surface water samples in some source areas, particularly Source Area 1 and 2 which have a significant history of fire training activities, earthen bunds and a number of drainage channels, there is the potential that the surface water samples collected within downstream ponds or channels do not reflect the maximum potential PFAS concentrations likely to be encountered within the source areas. It is however noted that the surface water sample collected from the pond within the Current Fire Training Area (Source Area 6), which directly receives runoff from hardstand areas where fire training is regularly undertaken, is likely to be representative of a worst-case scenario of the on base source areas across the BMA (refer to Section 9.1.6).

The on-base surface water was generally reported to be stagnant in most drainage channels and within the unnamed creek where samples were able to be collected. Although, dry and wet weather sampling has not been undertaken, it is likely that some dilution of PFAS in surface water may occur during / following a heavy rain event where considerable runoff occurs, especially within drainage channels further downstream. It is therefore, considered likely that the downstream samples collected from drainage channels and / or creeks during the investigation may have been more concentrated due to evaporation during dry weather. It is further noted that the initial stormwater runoff during a rain event (i.e. the first flush) may have a higher PFAS load and this has not been assessed, and warrants consideration in the development of the ongoing monitoring plan within PFAS Management Area Plan.

**Sediment**

Five proposed on-base sediment samples were not able to be collected as the ponds or creeks proposed for sampling were lined (concrete or other). As such there is some uncertainty in these areas as to whether the sediments present a direct risk or are acting as secondary source of impact to groundwater.

Three of these samples were located within source areas including SD305 (Source Area 2 – Base Fire Services Former Training Ground), SD338 (Source Area 5 – Petroleum Platoon Fuel Handling Facility) and SD336 (Source Area 6 – Current Fire Training Area). Uncertainty remains around the direct risk these sediments (if present) may present, however, the uncertainty is not considered to impact on the development and interpretation of the CSM, as soil, sediment and groundwater sampling was undertaken directly down-gradient of each of these locations.

The remaining two on-base sediment samples which were not able to be collected (SD366 and SD386) were located on North Bandiana where the drainage channel or unnamed creek was concrete lined. Again, uncertainty remains around the direct risk these sediments (if present) may present, however, the uncertainty is not considered to impact on the development and interpretation of the CSM, as down-gradient sediment and groundwater sampling was undertaken.

Two off-base samples (SD428 and SD429) and one point of use sample (SD461) along Jack in the Box Creek were not able to be collected as the drains were concrete lined. Within these portions of the creek, the concrete lined drains are unlikely to accumulate sediment, and any sediments would likely be scoured during significant rain events. The potential for the sediments within the Jack in the Box creek to be acting as a secondary source to groundwater is discussed further in Section 10.1.2. The two groundwater wells positioned adjacent to Jack in the Box Creek were sampled including MW360 and MW361, and provided sufficient initial
information on the CSM. However, the understanding of the surface water and groundwater interactions within the lower Jack in the Box creek is limited.

A further two of the four off-base samples (SD413 and SD445) were not able to be collected due to access restrictions, and uncertainty remains around the conditions of sediment in these areas. However, the locations are considered to be represented by the remaining off-base sediment samples.

10.3.2 Groundwater Sampling Representativeness

It was generally observed that groundwater wells screened within the Shepparton Colluvium had the highest electrical conductivities, and wells installed in the Coonambigdal Fluvium along the Kiewa River and in the Shepparton Fluvium on East Bandiana generally exhibited the lowest electrical conductivities. It is however noted that select groundwater wells installed within the Shepparton Colluvium had considerably lower electrical conductivities, in relation to nearby groundwater wells. These included:

- MW307 and MW306, which were installed in Source Area 1 had a considerably lower electrical conductivity than surrounding wells, however the groundwater composition (i.e. cations and anions) were not significantly different. PFAS compounds were detected in MW307, however were reported below the LOR in MW306. The variations may be due to the drilling technique used to install the wells (i.e. sonic drilling, which introduced mains water to lubricate and cool during drilling) and due to the low hydraulic conductivity of the formation, the drilling fluid may not have been fully recovered during the well development process. In the case of MW306, the well screen depth is screened approximately 5-10 m deeper than surrounding wells, and this may also contribute to the lower conductivities and the lower concentrations of PFAS.

- MW315 and MW317, which were installed in Source Area 2 and MW319, MW321 and MW359, which were installed in Source Area 7 reported lower conductivities between 444 µS/cm and 2310 µS/cm, and a groundwater composition that was not consistent with the surrounding formation. Like Source Area 1, this may be due to the drilling technique used to install the wells (i.e. sonic drilling), and the development limitation imposed by the low hydraulic conductivity of the formation. However, the variations may also be attributed to the geology, as these locations were installed in residual soils overlying the OMC. The groundwater wells installed in the OMC (i.e. MW336 and MW362) generally exhibited lower conductivities than the wells installed in the Shepparton Colluvium.

- MW328 which was installed in Source Area 6. The lower electrical conductivity in this well compared to surrounding wells is likely due to MW328 being installed at a significantly greater depth.

- MW313 which was installed within the residential estate west of South Bandiana reported lower electrical conductivities than expected. As discussed above, this may be due to the drilling technique used to install the well (i.e. sonic drilling) and the well development limitations. However, the reported PFAS concentrations are consistent with the surrounding wells.

Overall, there is a minor degree of uncertainty (above that typically associated with groundwater sampling) with the representativeness of the groundwater samples collected from monitoring wells installed using the sonic drilling techniques. Particularly those wells where large volumes of water (up to 2,500 L at MW318) were required to reach target depth, and where the development (i.e. removal of the drilling fluid) of the well was inhibited by the naturally low hydraulic conductivity of the geological formation. It is considered that due to the drilling technique and introduction of water, some localised dilution of PFAS in groundwater may have occurred.

Except for MW313 the influenced wells were not positioned near the Base boundaries and / or sensitive receptors, and all the influenced wells were assessing groundwater at depths generally greater than 20 m bgl and were installed in areas where groundwater extraction was not occurring. Furthermore, as demonstrated
by the difficulties encountered during the well development process, and by the field hydraulic conductivity
testing; the low yield of the formation is likely to inhibit future groundwater extraction in these areas. Therefore,
the uncertainty around the PFAS concentrations in the select groundwater wells does not negatively influence
conceptual understanding developed through the DSI (i.e. the SPR linkages). However, there is potential that
PFAS concentrations may increase in these wells as the aquifer returns to equilibrium.

10.3.3 Groundwater Flow Divide

The groundwater levels and contouring indicate the groundwater flow is generally following the topography.
Groundwater flows within the western portion of South Bandiana generally flows to the north to north-west
from the base of Bears Hill towards Jack in the Box Creek, then Wodonga Creek. And the groundwater on
North Bandiana generally appears to flow to the south-east, before slightly re-orientating more towards the
east and the Kiewa River. However, as North and South Bandiana are positioned across a topographic saddle
between Huon Hill and Bears Hill, there is a groundwater flow divide occurring beneath the site.

The groundwater divide appears to be generally consistent with topography and appears to be influenced
considerably by Bears Hill and Huon Hill. However, there is some uncertainty relating to the position of the
groundwater divide, due to the lack of groundwater data in the eastern portion of South Bandiana, particularly
to the east of MW337. These portions of the base were not investigated, as no PFAS source areas were
identified within the eastern portion of South Bandiana. Due to the position of the groundwater divide, there is
some uncertainty around the groundwater flow beneath Source Areas 8 and 9. PFAS impacts were not
identified within Source Area 8, however it is unclear if the PFAS impacts identified in the groundwater within
Source Area 9 are potentially migrating towards the Kiewa River or Jack in the Box Creek. It is noted however
that the evaluation of data has considered that these concentrations may migrate in either direction to the
relevant receptors in each direction.

Furthermore, the position of the groundwater divide is also potentially influencing the groundwater flow
direction beneath Source Area 6 (Current Fire Training Area), where groundwater flow was identified to be
travelling west, rather than north as inferred from the topography. As such, there is a potential data gap as
monitoring wells are not positioned to the west of the facility.

Overall, while there is some uncertainty around the position of the groundwater divide, and the potential flow
direction within the vicinity of Source Area 6 (Current Fire Training Area), the understanding of the
groundwater flow across the bases is considered sufficient to achieve the objectives of the investigation,
particularly regarding potential SPR linkages for on-base and off-base receptors. Further assessment of the
position of the groundwater divide and the flow direction in Source Area 6 should be considered should future
groundwater extraction be considered on the site.

10.3.4 Contaminant Nature and Extent

Some uncertainties remain regarding the nature and extent of the identified PFAS impacts both on the base
and within the off-base environments.

On-base, the extent of PFAS impacts have not been delineated in the following areas:

- The presence and extent of PFAS impacted soils potentially present within the on-base residential area
  adjacent to Source Area 7 (Old Fire Station).
- The extent of PFAS impacts identified exceeding the recreational screening guidance values within the
  impacted perched groundwater within Source Area 9 (POL – Building 490).

Within the off-base Jack in the Box Creek catchment, there is some uncertainty around the increase in PFAS
concentrations within the groundwater down the flow path. Groundwater concentrations of PFOS+PFHxS
were significantly higher, and above drinking water guidance values, for the two downstream off-base
groundwater wells (MW360 and MW361) installed in the sandier Shepparton Fluvium. These are positioned approximately 1.2 km and 2.7 km respectively from the nearest on-base source area (Source Area 1). The increase in concentrations of PFAS down the flow path may be due to a number of factors including:

- Contribution of alternative off-base sources of PFAS within the catchment given that MW360 and MW361 are located in a commercial / industrial setting where unidentified PFAS sources may exist.
- Concentrations of PFAS in surface water and sediment were identified along the length of Jack in the Box Creek. As such, the increase in concentrations could be attributed to the greater infiltration of surface water and fine sediments through the sandier Shepparton Fluvium within the lower catchment compared to the clay soils associated with the Shepparton Colluvium of the upper catchment. It is further noted that residual impacts within the sediment, especially within the deeper sediment profile, may also be leaching into the groundwater.

Furthermore, there is also uncertainty around the interaction between surface water and groundwater in the vicinity of the Jack in the Box Creek and Wodonga Creek confluence. There is potential PFAS concentrations identified above the drinking water guidance values in the lower Jack in the Box Creek catchment groundwater contributing to the PFAS concentrations identified within Wodonga Creek. The groundwater may also be interacting with surface water within the oxbow lakes identified within the small parcel of agricultural land on the southern bank of Wodonga Creek. Subject to the outcomes of the HHRA, an improved understanding of the nature of the groundwater and surface water interactions within the lower Jack in the Box Creek catchment and Wodonga Creek may be warranted.

Within the Kiewa River catchment, there is also some uncertainty regarding surface water and groundwater interactions. Groundwater impacts above the drinking water screening guidance values have not been delineated to the east of East Bandiana. While PFAS impacts were identified in groundwater near the confluence with the Kiewa River, the extent of impacts in groundwater along the unnamed creek east of North Bandiana have not been fully delineated. Furthermore, PFAS impacts exceeding the drinking water and recreational water guidance values were also identified in surface water samples collected from oxbow lakes to the east and north-east of East Bandiana, located along the western bank of the Kiewa River floodplain. And the interactions between surface water and groundwater within the Kiewa River floodplain are not understood. Subject to the outcomes of the HHRA, an improved understanding of the nature of the groundwater and surface water interactions within the Kiewa River floodplain may be warranted.

While many of the smaller surface water features across the investigation area were dry at the time of sampling, the sampling completed within the rivers and oxbows was completed during the seasonal high water. As such, there is potential the samples collected during the DSI represent dilute conditions. The investigation understands from North East Water that an ongoing PFAS sampling program associated with off-take water from Wodonga Creek is being conducted by North East Water involving the analysis of more than 60 samples including during low-flow periods consistently reported levels of PFAS well below drinking water screening guidance values. Additional seasonal monitoring as part of this investigation is warranted to understand the potential seasonal variation in PFAS concentrations within the investigation area, and the associated potential risk.

10.3.5 PFAS Precursors and Transformation

Some PFAS compounds have the ability to undergo transformation under aerobic conditions to form stable PFAS compounds at degradation such as perfluoroalkyl carboxylates (PFCAs) (e.g. PFOA) with a carbon chain length of C8 or higher, or perfluoroalkyl sulfonates (PFSAs) (e.g. PFOS and PFHxS) with a carbon chain length of C6 or higher. These compounds are termed ‘precursors’, and can be both known and unknown PFAS compounds. Precursors include some PFAS compounds which are currently able to be analysed by commercial laboratories such as fluorotelomers and perfluoroalkane sulfonamides (FASAs). However,
precursors may also include PFAS compounds which are generally not part of the typical PFAS laboratory analytical suite. Therefore, the identification of precursors may contribute to the following:

- An increase in the total concentration of stable compounds such as PFOS and PFOA through transformation of precursors which can currently be analysed by laboratories (such as 6:2 FTS) and transformation of precursors which are currently not part of the laboratory analytical suite; and
- An increase in the measured overall mass of total PFAS through transformation of precursors which are currently not part of the laboratory analytical suite.

The presence of precursors may be identified through analytical techniques such as Total Oxidisable Precursor Assay (TOPA) or Total Organic Fluorine (TOF). As such TOPA and TOF may be used to determine the potential total future concentration of stable PFAS compounds such as PFOS and PFOA, and the total overall mass of PFAS, should transformation occur. However, while TOPA and TOF may assist in determining the future concentration of stable PFAS compounds and total mass of PFAS present, there are some limitations with these analytical techniques. These include the following:

- There is no standardised method for undertaking TOPA analysis; the methods to not identify which PFAA precursors may be present in the sample analysed; cannot be relied upon to quantify the mass of PFAS within a sample and the strongly oxidising, heated and alkaline conditions that the samples are subjected to during laboratory analysis are not considered to be representative of those naturally occurring within the environment, and therefore do not inform the potential transformation rates or risks.
- TOF analysis only provides a measurement of total fluorine and the results may be used to calculate hypothetical equivalents of stable PFAS compounds in a sample.

As stated in the NEMP (2018), the transformation of precursors is likely to be facilitated where AFFF has been released into the wider environment subject to aerobic conditions. As TOPA or TOF analysis was not included within the DSI analytical suite, there is uncertainty on what (if any) precursors are present and whether concentrations of stable PFAS concentrations (such as PFOS and PFOA which are within the current laboratory analytical suite) will increase in the future as precursors degrade.

Overall, it is considered that the application of TOPA and TOF would be most relevant during remediation phases, especially if strong oxidants were to be utilised, or to inform potential future risk or management plans to help identify the potential longevity of the PFAS impacts.

11.0 CONCLUSIONS

Based on the sampling conducted and the understanding of the CSM, the following conclusions are made:

- 15 on-base potential source areas were identified, and the intrusive investigations confirmed PFAS contamination in 12 on-base source areas.
- The pathway for PFAS migration from the source areas on South and North Bandiana is predominately through surface waters, while the pathway for PFAS migration from the source areas on East Bandiana appears to be influenced by both the surface water and groundwater migration toward the Kiewa River.
- The BMA is situated within an area that was previously predominantly rural agricultural land, however, the urban residential areas of Wodonga are progressively expanding and altering the land use in areas surrounding the BMA. The waterbodies on- and off-base meet varied descriptions of ecosystem disturbance and modification ranging from highly modified to slightly-to moderately disturbed.
- The following potential linkages between the BMA derived PFAS and the human and ecological receptors have been identified:
Potential Human Health Risks – On-base:

- Based on the sampling results within both the source areas and their surrounds on the BMA, and based on the way the land is used, the concentrations of PFAS in the soil are not considered to present a risk.

- Surface water across the BMA was identified as having PFAS concentrations above the guidance values. However, as people do not swim in or routinely interact with the surface water, exposure is limited and the water is unlikely to present a risk. However, it is important to ensure appropriate health and safety precautions are implemented when people on the base are either involved in maintenance activities, or involved in training which use and/or involve surface water.

- Within localised areas across North and South Bandiana the groundwater was identified as having PFAS concentrations above the guidance values. However, as the water table is generally deep, and groundwater is not extracted on the base, these impacts are not considered to present a risk. However, within an area localised around the Petroleum, Oils and Lubricants facility (Source Area 9) on South Bandiana and beneath East Bandiana the groundwater is not as deep. Therefore, it is important to ensure appropriate health and safety precautions are implemented for construction and maintenance activities which may encounter groundwater in these areas.

- Due to the tendency for PFAS to accumulate within plants and animals, further investigation is required to assess if the PFAS identified on the base are accumulating in the sheep grazing on the base. The level of associated with this potentially complete pathway will be the subject of a Human Health Risk Assessment.

Potential Human Health Risks – Off-base:

- Water extracted from Wodonga Creek, including that by North East Water for the municipal town supply, is below drinking water guidance values. As such, it is safe to continue to drink the municipal water supply.

- Based on outcomes of other studies conducted in Australia, concentrations of PFAS in water equivalent to the drinking water guidance values were considered safe to use for garden, poultry and stock watering. The Human Health Risk Assessment will provide the mechanism of validating these findings considering the site specific data collected.

- For recreational uses – the soil, sediment and surface water PFAS concentrations along the majority of the Jack in the Box Creek (including along Arthur Dunstan Park), within Wodonga Creek, and within the main flowing channel of the Kiewa (where swimming and boating occur), were below the guidance values. Based on these current results collected in high flow conditions, it is safe to continue to swim in these areas.

- However, PFAS in surface water sampled in two specific locations within Jack in the Box Creek immediately downstream of the base, and in surface water and sediment in the oxbow lakes to the east of East Bandiana, were higher than the guidance values. The level of risk in these areas will be the subject of a Human Health Risk Assessment.

- Due to the tendency for PFAS to accumulate within plants and animals, further investigation is required to assess if the PFAS identified within the Jack in the Box Creek, Wodonga Creek and Kiewa River are accumulating in the food people are either growing or catching. The level of risk in these areas will be the subject of a Human Health Risk Assessment.
### Potential Ecological Risks:

- The concentrations of PFAS in soil, sediment and surface water, both on-base and off-base in both the Jack in the Box Creek and Kiewa River catchments, were higher than the screening values used for identifying potential ecological risk. It is worth noting that, due to the tendency for PFAS to accumulate in animals and magnify within ecological food chains, the ecological screening guidance values are very low (i.e. close to the laboratory reporting limit). The level of risk will be the subject of an Ecological Risk Assessment.

- The DSI was completed in accordance with the guidance presented in the NEPM 1999, as amended in 2013, and thereby achieves the initial program objective established by Defence. Based on the investigation results and through the understanding of the CSM, the DSI also achieves the task objectives specific to the DSI, which included:
  - The DSI completed a comprehensive assessment of the BMA and surrounding area to confirm that the on-base and off-base community stakeholders have access to safe drinking water that has not been affected by PFAS contamination.
  - The DSI identified and assessed off-base land and water use that may be associated with the human food chain.
  - The DSI identified potential sources of PFAS contamination associated with the former practices, storage and waste management of historical AFFF products on the Defence Estate (i.e. BMA).
  - In accordance with the DQOs established within the Auditor approved SAQP, the DSI characterised to the extent practicable, the nature and migration potential of PFAS contamination both laterally and vertically from the base and allowed an initial screening assessment of the potential risks to receptors.

### 11.1 What are the next steps?

The investigation findings have established a greater understanding of PFAS on and around the BMA, and identified that many of the potential PFAS exposure pathways do not present a risk to people both on and off the base. There is however, in specific areas as described above, the need to undertake further investigation to confirm if an unacceptable human health or ecological risks are present and what management / remedial measures need to be implemented.

To investigate these risks, the next step that will be undertaken is a Human Health and Ecological Risk Assessment (HHERA) and the development of the PFAS Management Area Plan (PMAP). This process will commence in the second quarter of 2018. The HHERA will involve collecting samples of water, fish and other aquatic biota that people and animals may eat.

### 12.0 IMPORTANT INFORMATION

Your attention is drawn to the document, ‘Important Information Relating to this Report’, which is included in Appendix Q of this report. The statements presented in this document are intended to advise you of what your realistic expectations of this report should be, and to present you with recommendations on how to minimise the risks associated with the services provided for this project. The document is not intended to reduce the level of responsibility accepted by Golder Associates, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing.
Signature Page

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